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ABSTRACT

This packet contains both teacher and student materials for a course on agricultural structures. The curriculum contains seven units, each containing several lessons, on the following topics: (1) working with plans; (2) home and farmstead planning; (3) building construction; (4) concrete; (5) electricity; (6) plumbing; and (7) fencing. The instructor guide includes the following instructional components: objectives, competencies, motivational techniques, teaching procedures, other activities, activity sheets, transparency masters, evaluations, answers to evaluations and activity sheets, references and teaching aids, and materials and equipment list. The student reference contains information sheets for each of the lessons. (KC)

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Agricultural Structures

INSTRUCTOR GUIDE

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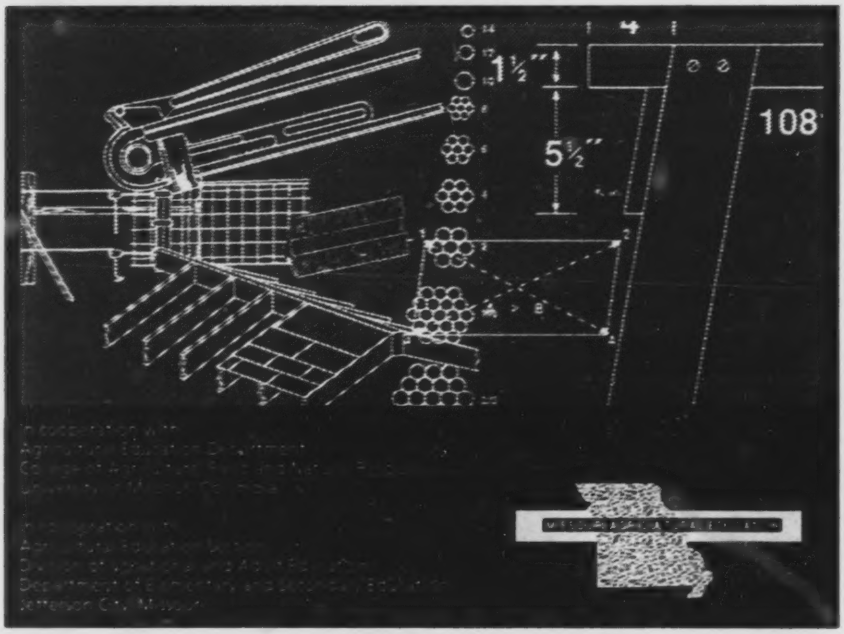

In cooperation with
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In cooperation with
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AGRICULTURAL STRUCTURES

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FOREWORD

The development of the *Agricultural Structures* curriculum guide is the result of suggestions by the MVATA Teaching Aids Committee. The Agricultural Structures Advisory Committee suggested the topics to be included and reviewed the materials.

This curriculum contains seven units. The instructor guide includes: objectives, competencies, motivational techniques, teaching procedures, other activities, activity sheets, transparency masters, evaluations, answers to evaluations and activity sheets, references and teaching aids, and materials and equipment. Topics include working with plans, home and farmstead planning, building construction, concrete, electricity, plumbing, and fencing. One copy of the student reference is packaged with the instructor guide. Additional copies of the student reference can be purchased separately.

During the summer of 1981, the Missouri State Board of Education formally adopted the concept of "Instructional Management Systems" (IMS) as a priority for the 1981-82 school year. The Missouri Commissioner of Education described the IMS concept as a practical way of "organizing for excellence" in education. To meet the demand for greater productivity and accountability, the director of Vocational Education applied the elements of IMS to form the Vocational Instructional Management System (VIMS). The VIMS process provides a framework to use in planning and organizing to assure excellence in Missouri's vocational education system by focusing greater attention on the management of teaching and learning.

This guide incorporates the needed components to aid agriculture teachers in the implementation of VIMS. For ease of use, performance objectives and competencies have been included at the beginning of the guide as well as incorporated within each lesson. A competency profile has been provided in the front of the guide for convenient record keeping. A table is included to show how the competencies in *Agricultural Structures* relate to the Show-Me Standards and Curriculum Frameworks. *Agricultural Structures* is in the Natural Resources career path.

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AGRICULTURAL STRUCTURES

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COMPETENCIES/OBJECTIVES

UNIT I - WORKING WITH PLANS

1. Read and create a simple construction drawing.
2. Develop a plan of procedure and a bill of materials for a construction project.

UNIT II - FARMSTEAD PLANNING

1. Evaluate a site for a home.
2. Arrange a farmstead.
3. Describe characteristics of disposal systems for managing livestock manure.

UNIT III - BUILDING CONSTRUCTION

1. Describe safety practices associated with building construction.
2. Identify types and designs of buildings and their methods of construction.
3. Identify and select building materials.
4. Identify the uses of different fasteners and fastening systems.
5. Describe how to construct a floor and subfloor.

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COMPETENCIES/OBJECTIVES

UNIT I - WORKING WITH PLANS

1. Read and create a simple construction drawing.
2. Develop a plan of procedure and a bill of materials for a construction project.

UNIT II - FARMSTEAD PLANNING

1. Evaluate a site for a home.
2. Arrange a farmstead.
3. Describe characteristics of disposal systems for managing livestock manure.

UNIT III - BUILDING CONSTRUCTION

1. Describe safety practices associated with building construction.
2. Identify types and designs of buildings and their methods of construction.
3. Identify and select building materials.
4. Identify the uses of different fasteners and fastening systems.
5. Describe how to construct a floor and subfloor.

6. Describe the purposes of walls, types of walls, supports, and siding used in agricultural buildings.
7. Select a roof support system.
8. Select roofing materials.
9. Identify factors affecting the heating, cooling, and ventilation of agricultural structures.

UNIT IV - CONCRETE

1. Discuss safety in working with concrete.
2. Identify factors that affect the quality of fresh concrete.
3. Identify site preparation requirements.
4. Describe the procedure for preparing to pour a concrete slab.
5. Explain the procedure for ordering, pouring, and finishing concrete.
6. Identify factors affecting the quality of cured concrete.
7. Describe the procedure for pouring a concrete wall.

UNIT V - ELECTRICITY

1. Identify the terms, dangers, and safety practices associated with electrical work.
2. Identify the terms associated with electrical work.
3. Match types and sizes of wire with their uses.
4. Identify the importance of grounding and GFCI protection.
5. Locate lights, outlets, and switches, and identify circuit protection needs.
6. Identify the symbols used in agricultural wiring plans.
7. Describe practices for running wire to an agricultural structure and wiring within the building safely.
8. Identify procedures for connecting the drop wires and branch circuit wires to the SEP.
9. Describe how to run wiring from the SEP to a junction box, lights, and receptacles.
10. Calculate cost and electrical power using Ohm's Law.
11. Describe procedures for planning and installing lightning protection.
12. Identify problems in electrical systems.

UNIT VI - PLUMBING

1. Calculate how much water is needed for a farmstead.
2. Discuss safety practices for plumbing.
3. Identify pipe types and determine size requirements.
4. Measure, cut, and connect pipes and tubing.
5. Identify methods of protecting water pipes against freezing.

UNIT VII - FENCING

1. Discuss the terminology, dangers, and safety practices associated with building fences.
2. Describe how to set and brace wood and steel posts.
3. Describe techniques for building barbed and woven wire fences.
4. Describe techniques for building high tensile and electric fences.
5. Identify fence mending techniques.

EVALUATION

1. Give short, objective tests following each lesson and a more in-depth objective test at the conclusion of the unit.
2. Observe the changes in behavior as evidence of the improved ability of students to deal with problems in this unit using background information acquired from earlier units.
3. Observe students' attempts to solve similar problems in their supervised agricultural experience programs.

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2) *Constructing Electric Fences for Cattle (G1190).* University Extension Agricultural Publications, 1993.

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4) How to Size a Farm and Home Water System (G1801). University Extension Agricultural Publications. University of Missouri-Columbia.

5) *Lightning Protection for Missouri Farms and Homes (G1020).* University Extension Agricultural Publications, 1993.

6) Missouri Fencing and Boundary Laws (G810). University Extension Agricultural Publications, 1993.

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8) Kidwell, Boyd. "Choosing a Charger." *Progressive Farmer.com* http://progressivefarmer.com/equipment/1098/fence/choose.html (20 May 1999).

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9) Mississippi State University Extension Service. *Frozen Pipes: Causes and Cures.* http://www.ext.msstate.edu/pubs/is1438.htm (25 September 1998).

10) Missouri Department of Natural Resources. "Division of Energy." http://www.dnr.state.mo.us/de (25 January 1999).

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12) State Farm Educational Materials. "Lightning Protection." http://www5.statefarm.com/educate/lightnin.htm (8 Feb. 1999).

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MATERIALS AND EQUIPMENT FOR ACTIVITIES

1. Unit 1, Lesson 1: Drawing a Plan

Computer with CAD software and printer (if possible)
Paper, either plain white copy paper or high rag content drawing paper (if professional hand drawing instruments are available)
No. 2 lead pencil
Ruler or architect's scale

2. Unit 3, Lesson 5: Joist Layout

10 8-foot 2" × 8" boards
[illegible]-foot 2" × 8" boards
16d duplex head nails

Circular or radial arm saw
Hammer
Tape measure

3. Unit 3, Lesson 7: Rafter Layout

Pencil and paper
Carpenter's framing square
Boards, strips of construction paper, cardboard, or rolls of fax paper

4. Unit 3, Lesson 8: Applying Roofing Materials

Classroom or shop tables
Paper models of shingles

5. Unit 4, Lesson 3: Laying Out a Building

4 stakes
2 tape measures
Twine

6. Unit 4, Lesson 4: Reinforcing Concrete

1 8-foot 1" × 6" board
20 16d duplex-head nails
⅛" welding wire
Wax paper or plastic wrap
Latex gloves
Eye protection
Concrete mix

7. Unit 4, Lesson 5: Pouring a Concrete Curb

Wood and duplex nails for forms
Tape measure
Concrete
2 1" pipes, 1' long
Wire
Rebar
Wire for rebar supports
Shovel or spade
Oil
Hand trowel
Board for screed
Latex gloves
Eye protection

8. Unit 4, Lesson 6: Curing Concrete

Mixed concrete
15 3" pieces of PVC pipe, 6" long
Hydraulic press
Oil (new motor oil)
¼" steel rod, 8" long
4' × 4' piece of plywood or sheet metal
Buckets
Oven

Freezer
Sand

9. Unit 4, Lesson 7: Preparing Forms for a Concrete Wall

Plywood
16d duplex-head nails
4 snap ties
8 snap tie holders
2 8-foot 2" × 4" boards for wales and braces
1 4-foot 1" × 4" board for ties
Wire for wire ties
2" × 4" scraps for spreaders
Electric drill and bits
Level

10. Unit 5, Lesson 9: Wiring a Three-Way Switch

Mock wall with two switch boxes and one light fixture already attached
1 12-2 NMC cable, 16 inches long
2 12-3 NMC cables, 30 inches long
2 three-way switches
Light fixture
Solderless connectors
Three-prong plug
Screw driver set
Wire strippers
Cable rippers

11. Unit 5, Lesson 12: Using Testing Devices

Neon tester
Voltage tester
VOM meter

12. Unit 6, Lesson 4: Cutting and Joining Plastic Pipe

1" PVC pipe, 4 feet in length
4 1-inch 90-degree PVC elbows
1 1-inch PVC T
1 1-inch PVC cap
Tape measure
Hacksaw
PVC primer and glue (optional)
Sandpaper

13. Unit 6, Lesson 4: Sweating Copper Pipe

1 1" copper pipe, 4 inches in length
1 1" cap
Flux
Brush
Propane torch
Stationary vise
Steel wool or sandpaper

14. Unit 7, Lesson 2: Constructing Model Brace Assemblies

1 8-foot 2" × 4"
1 4-foot ½" dowel
Hacksaw
½-inch drill bit
Drill
Wood glue
Wood chisel
1 12d nail
2 feet of thin wire (.035 MIG wire)

15. Unit 7, Lesson 3: Constructing Barbed Wire Fencing

Barbed wire
Fence stretchers
Metal fence posts
Metal post driver
Wire clips
Fencing pliers
Standard screwdriver
Claw hammer
Fencing staples

16. Unit 7, Lesson 4: Tensioning Fences

14-gauge soft wire
Strainer
Wire cutters

17. Unit 7, Lesson 5: Splicing Wire

14-gauge soft electric wire, cut into four 2-foot pieces
Compression sleeve
Sleeve compressor or fencing pliers

Agricultural Structures - Competency Crosswalk

Duty Band and Task Statement	SHOW-ME STANDARDS		CURRICULUM FRAMEWORKS					
	Knowledge (Content)	Performance (Goals)	Math	Communication Arts	Science	Social Studies	Health/ Physical Education	Fine Arts
A-1	FA-4 CA-3 MA-2	1.4, 1.5, 1.6, 1.8, 2.1, 2.5, 4.1	MA/VI/9-12/3a, 3b	CA/I/9-12/3b CA/II/9-12/2c CA/II/9-12/3c CA/II/9-12/4i CA/III/9-12/1j				FA/IV-A/9-12/6a
A-2	MA-1 CA-1	1.4, 1.6, 2.1, 3.2	MA/V/9-12/1a MA/IV/9-12/3a, 3b, 3c, 3d	CA/II/9-12/1a, 1b				
B-1	SC-4, SC-8 SS-5, SS-6, SS-7 CA-3	1.1, 1.2, 1.4, 1.10, 2.3, 3.1, 3.8, 4.1, 4.2		CA/IV/9-12/1a, 1b, 1c, 1d, 1e, 1f, 1g, 1h, 1i	SC/VIII-A/9-12/2a SC/VIII-B/9-12/2a	SS/IV-A/9-12/3a, 3b, 3c, 3d, 3e, 3f, 3g, 3h, 3i SS/IV-B/9-12/1a, 1b, 1c, 1d, 1e, 1f, 1g, 1h, 1i		
B-2	SC-1,SC-2, SC-5,SC-8 SS-5	1.2, 1.4, 2.3, 3.1, 3.2, 3.3, 3.5, 3.6, 3.7, 3.8			SC/II-A/9-12/2a SC/VIII-A/9-12/2b SC/VIII-B/9-12/2a, 2b, 2c	SS/IV-A/9-12/3a, 3b, 3c, 3d, 3e, 3f, 3g, 3h, 3i SS/IV-B/9-12/1a, 1b, 1c, 1d, 1e, 1f, 1g, 1h, 1i		
B-3	SC-8 CA-3	1.4, 1.5, 3.1, 3.2, 3.3, 3.5, 3.6, 3.7, 4.7		CA/I/9-12/1b, 1d CA/I/9-12/2a, 2b, 2c, 2d, 2e CA/1/9-12/3a, 3b, 3c, 3d, 3e	SC/VIII-B/9-12/1a			
C-1	HPE-6 CA-3	1.2, 1.10, 3.2, 3.3, 4.7	CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h				HPE/III-B/9-12/5a	
C-2	CA-3 MA-2	1.2, 1.7, 2.5 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8	MA/VI/9-12/2a	CA/I/9-12/1b CA/IV/9-12/1a, 1b, 1c, 1d, 1e, 1f, 1g, 1h				

	SHOW-ME STANDARDS		CURRICULUM FRAMEWORKS					
Duty Band and Task Statement	Knowledge (Content)	Performance (Goals)	Math	Communication Arts	Science	Social Studies	Health/ Physical Education	Fine Arts
C-3	CA-3	1.1, 1.4, 1.8, 1.10, 3.1, 3.5, 3.8		CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h				
C-4	SC-2	1.2			SC/IV-C/9-12/1a			
C-5	MA-1	1.3, 1.10, 2.5, 3.1, 3.2, 4.6, 4.7	MA/IV/9-12/3a, 3b, 3c, 3d, 3e					
C-6	MA-2	1.3, 1.5, 2.5, 3.5	MA/IV/9-12/3a, 3b, 3c, 3d, 3e MA/VI/9-12/1b, 1d, 1i, 1k, 1l, 2b, 2d, 2i, 2k, 2l, 3b, 3d, 3i, 3k, 3l					
C-7	MA-2	1.3, 1.5, 2.5, 3.5	MA/IV/9-12/3a, 3b, 3c, 3d, 3e MA/VI/9-12/1b, 1d, 1i, 1k, 1l, 2b, 2d, 2i, 2k, 2l, 3b, 3d, 3i, 3k, 3l					
C-8	CA-3 SC-1	1.2, 1.3, 1.5, 3.5, 4.1		CA/I/9-12/1b	SC/II-A/9-12/1c			
C-9	SC-8 CA-3	1.1, 1.2, 1.3, 1.4, 1.8, 2.5, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7		CA/I/9-12/1b CA/I/9-12/2c	SC/III-B/9-12/2a SC/III-C/9-12/4a			
D-1	CA-3 HPE-6	1.2, 1.4, 3.2, 3.3, 4.7		CA/I/9-12/1b CA/II/9-12/1c CA/IV/9-12/1c, 1d, 1e, 1h			HPE/III-B/9-12/5a	
D-2	SC-8 MA-1	1.2, 1.3, 1.4, 1.6, 1.8, 2.5, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8	MA/IV/9-12/2b, 2c, 2d, 3b, 3c, 3d		SC/III-B/9-12/1a			

Duty Band and Task Statement	SHOW-ME STANDARDS		CURRICULUM FRAMEWORKS					
	Knowledge (Content)	Performance (Goals)	Math	Communication Arts	Science	Social Studies	Health/ Physical Education	Fine Arts
D-3	CA-3 MA-1, 2		MA/IV/9-12/2a, 2b, 2d, 3a, 3b, 3d	CA/I/9-12/1b CA/II/9-12/1c				
D-4	CA-3	1.2, 1.4, 1.5, 1.7, 1.8, 3.2, 3.3, 3.5, 3.7, 3.8		CA/1/9-12/Ib CA/II/9-12/1c CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h				
D-5	SC-8 CA-3 MA-1, 2	1.2, 1.3, 1.5, 1.8, 1.10, 2.5, 2.6, 3.2, 3.3, 3.7, 3.8	MA/I/9-12/4a, 4b, 4c, 4d, 4e MA/III/9-12/1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 4a, 4b, 4c, 4d, 5a, 5b, 5c, 5d MA/IV/9-12/2a, 2b, 2c, 2d, 2e, 3a, 3b, 3c, 3d, 3e MA/VI/9-12/1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 3a, 3b, 3c, 3d	CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h, 2c, 2d, 2e, 2f, 2g, 2h, 3c, 3d, 3e, 3f, 3g, 3h	SC/III-B/9-12/1a			
D-6	SC-8	1.2, 1.3, 1.5, 1.8, 1.10, 2.5, 2.6, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8			SC/III-B/9-12/1a			
D-7	SC-8 CA-3 MA-1, 2	1.2, 1.3, 1.5, 1.8, 1.10, 2.5, 2.6, 3.2, 3.3, 3.7, 3.8	MA/I/9-12/4a, 4b, 4c, 4d, 4e MA/III/9-12/1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 4a, 4b, 4c, 4d, 5a, 5b, 5c, 5d MA/IV/9-12/2a, 2b, 2c, 2d, 2e, 3a, 3b, 3c, 3d, 3e MA/VI/9-12/1a, 1b, 1c, 1d, 2a, 2b, 2c, 2d, 3a, 3b, 3c, 3d	CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h, 2c, 2d, 2e, 2f, 2g, 2h, 3c, 3d, 3e, 3f, 3g, 3h	SC/III-B/9-12/1a			

Duty Band and Task Statement	SHOW-ME STANDARDS		CURRICULUM FRAMEWORKS					
	Knowledge (Content)	Performance (Goals)	Math	Communication Arts	Science	Social Studies	Health/ Physical Education	Fine Arts
E-1	HPE-6	1.1, 1.2, 1.3, 1.4, 1.5, 1.8, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7					HPE/III-D/9-12/1a, 1b	
E-2	CA-3			CA/I/9-12/1b CA/I/9-12/2c				
E-3	SC-8 CA-3	1.2, 1.3, 1.4, 1.8, 2.5, 2.6, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7		CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h	SC/III-B/9-12/1a			
E-4	HPE-6	1.2, 1.4, 1.8, 2.6, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 4.7					HPE/III-D/9-12/1a, 1b	
E-5	CA-3 HPE-6	1.2, 1.3, 1.4, 1.8, 2.5, 2.6, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 4.7		CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h CA/IV/9-12/2c			HPE/III-D/9-12/1a, 1b	
E-6	CA-3	1.2, 1.4, 1.8, 2.6, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7		CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h CA/IV/9-12/2c				
E-7	HPE-6 SC-8 CA-3	1.2, 1.3, 1.4, 1.7, 1.8, 2.6, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 4.7		CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h	SC/III-B/9-12/1a		HPE/III-D/9-12/1a, 1b	
E-8	HPE-6 SC-8 CA-3	1.2, 1.3, 1.4, 1.7, 1.8, 2.6, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 4.7		CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h	SC/III-B/1a		HPE/III-D/9-12/1a, 1b	

	SHOW-ME STANDARDS		CURRICULUM FRAMEWORKS					
Duty Band and Task Statement	**Knowledge (Content)**	**Performance (Goals)**	**Math**	**Communication Arts**	**Science**	**Social Studies**	**Health/ Physical Education**	**Fine Arts**
E-9	HPE-6 SC-8 CA-3	1.2, 1.3, 1.4, 1.7, 1.8, 2.6, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 4.7		CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h	SC/III-B/9-12/1a		HPE/III-D/9-12/1a, 1b	
E-10	MA-1,3 HPE-6 SC-8	1.1, 1.2, 1.4, 1.8, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 4.7	MA/IV/9-12/2a, 2b, 2c, 2d, 3a, 3b, 3c, 3d MA/V/9-12/1a, 1b, 1c, 2a, 2b, 2c		SC/III-B/9-12/1a		HPE/III-D/9-12/1a	
E-11	HPE-6 SC-8 CA-3	1.2, 1.3, 1.4, 1.7, 1.8, 2.6, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 4.7		CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h	SC/III-B/9-12/1a		HPE/III-D/9-12/1a, 1b	
E-12	CA-3 SC-1 HPE-6	1.1, 1.2, 1.4, 1.8, 1.10, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 4.7		CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h	SC/III-B/9-12/4a		HPE/III-D/9-12/1a	
F-1	MA-1 SC-8	1.2, 1.4, 1.8, 1.10, 3.2, 3.3, 3.5, 3.6, 3.7	MA/V/9-12/1a		SC/VIII-A/9-12/3b			
F-2	HPE-6 CA-3	1.2, 1.3, 1.7, 1.8, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7		CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h			HPE/III-D/9-12/1a, 1b	
F-3	CA-3 MA-1, 2	1.2, 1.4, 1.8, 2.5, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7	MA/V/9-12/1a MA/VI/9-12/1b, 1c, 1d, 2b, 2c, 2d, 3b, 3c, 3d	CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h				

	SHOW-ME STANDARDS		CURRICULUM FRAMEWORKS					
Duty Band and Task Statement	Knowledge (Content)	Performance (Goals)	Math	Communication Arts	Science	Social Studies	Health/ Physical Education	Fine Arts
F-4	HPE-6 CA-3 MA-1	1.2, 1.3, 1.4, 1.8, 2.5, 2.6, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 4.7	MA/I/9-12/1a, 1b, 1c, 1d, 1e, 2a, 2b, 2c, 2d, 2e, 3a, 3b, 3c, 3d, 3e, 4a, 4b, 4c, 4d, 4e	CA/IV/9-12/1c, 1d, 1e, 1f, 1g, 1h			HPE/III-D/9-12/1a, 1b	
F-5	CA-3	1.2, 1.4, 1.8, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7	CA/I/9-12/1b CA/III/9-12/1a, 1b, 1c, 1d, 1e, 1f, 1g, 1h, 1i,1j					
G-1	HPE-6 CA-3	1.2, 1.3, 1.7, 1.8, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7		CA/I/9-12/1b CA/III/9-12/1a, 1b, 1c, 1d, 1e, 1f, 1g, 1h, 1i, 1j			HPE/III-D/9-12/1a, 1b	
G-2	MA-1	1.2, 1.3, 1.4, 1.8, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7	MA/IV/9-12/3a, 3b, 3c, 3d, 3e MA/I/9-12/1a, 1b, 1c, 1d, 1e, 2a, 2b, 2c, 2d, 2e, 3a, 3b, 3c, 3d, 3e, 4a, 4b, 4c, 4d, 4e	CA/I/9-12/1b				
G-3	MA-1	1.2, 1.3, 1.4, 1.8, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7	MA/IV/9-12/3a, 3b, 3c, 3d, 3e MA/I/9-12/1a, 1b, 1c, 1d, 1e, 2a, 2b, 2c, 2d, 2e, 3a, 3b, 3c, 3d, 3e, 4a, 4b, 4c, 4d, 4e	CA/I/9-12/1b				
G-4	MA-1	1.2, 1.3, 1.4, 1.8, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7	MA/IV/9-12/ 3a, 3b, 3c, 3d, 3e MA/I/9-12/ 1a, 1b, 1c, 1d, 1e, 2a, 2b, 2c, 2d, 2e, 3a, 3b, 3c, 3d, 3e, 4a, 4b, 4c, 4d, 4e	CA/I/9-12/1b				

Duty Band and Task Statement	SHOW-ME STANDARDS		CURRICULUM FRAMEWORKS					
	Knowledge (Content)	Performance (Goals)	Math	Communication Arts	Science	Social Studies	Health/ Physical Education	Fine Arts
G-5	CA-3	1.2, 1.3, 1.4, 1.5, 2.5, 2.6, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7		CA/I/9-12/1b CA/III/9-12/1a, 1b, 1c, 1d, 1e, 1f, 1g, 1h, 1i, 1j				

AGRICULTURAL STRUCTURES

TEACHING CALENDAR

	Periods for Classroom Instruction/Activities	Length for Activity Sheets (AS)
Unit I, Lesson 1	6	AS 1.1 30 min.
		AS 1.2 1 class period
Unit I, Lesson 2	5	AS 2.1 30 min.
Unit II, Lesson 1	6	AS 1.1 1 class period
Unit II, Lesson 2	15	AS 2.1 1 class period
		AS 2.2 2 class periods
Unit II, Lesson 3	2	AS 3.1 1 class period
Unit III, Lesson 1	1	AS 1.1 30 min.
Unit III, Lesson 2	2	AS 2.1 1 class period
Unit III, Lesson 3	3	AS 3.1 1 class period
Unit III, Lesson 4	4	AS 4.1 1 class period
Unit III, Lesson 5	5	AS 5.1 30 min.
		AS 5.2 1 class period
Unit III, Lesson 6	5	AS 6.1 30 min.
Unit III, Lesson 7	6	AS 7.1 1 class period
Unit III, Lesson 8	4	AS 8.1 1 class period
Unit III, Lesson 9	2	AS 9.1 1 class period
Unit IV, Lesson 1	2	AS 1.1 1 class period
Unit IV, Lesson 2	3	AS 2.1 30 min.
Unit IV, Lesson 3	3	AS 3.1 1 class period
		AS 3.2 30 min.
Unit IV, Lesson 4	5	AS 4.1 2 class periods
Unit IV, Lesson 5	10	AS 5.1 2 class periods
Unit IV, Lesson 6	4	AS 6.1 1 class period
Unit IV, Lesson 7	5	AS 7.1 1 class period
Unit V, Lesson 1	2	AS 1.1 1 class period
Unit V, Lesson 2	2	AS 2.1 30 min.
Unit V, Lesson 3	5	AS 3.1 30 min.
Unit V, Lesson 4	3	AS 4.1 30 min.

	Periods for Classroom Instruction/Activities	Length for Activity Sheets (AS)
Unit V, Lesson 5	3	AS 5.1 1 class period
Unit V, Lesson 6	1	AS 6.1 30 min.
Unit V, Lesson 7	3	AS 7.1 30 min.
Unit V, Lesson 8	7	AS 8.1 30 min.
Unit V, Lesson 9	8	AS 9.1 1 class period
Unit V, Lesson 10	2	AS 10.1 30 min.
Unit V, Lesson 11	2	AS 11.1 30 min.
Unit V, Lesson 12	3	AS 12.1 30 min.
Unit VI, Lesson 1	3	AS 1.1 30 min.
Unit VI, Lesson 2	1	AS 2.1 15 min.
Unit VI, Lesson 3	3	AS 3.1 1 class period
Unit VI, Lesson 4	5	AS 4.1 1 class period
		AS 4.2 30 min.
Unit VI, Lesson 5	2	AS 5.1 30 min.
Unit VII, Lesson 1	2	AS 1.1 30 min.
Unit VII, Lesson 2	3	AS 2.1 1 class period
Unit VII, Lesson 3	5	AS 3.1 1 class period
Unit VII, Lesson 4	5	AS 4.1 30 min.
Unit VII, Lesson 5	2	AS 5.1 15 min.

35

AGRICULTURAL STRUCTURES
Competency Profile

Directions: Evaluate the student by checking the appropriate number or letter to indicate the degree of competency. The rating for each task should reflect **employability readiness** rather than the grades given in class.

Rating Scale:
3 Mastered - can work independently with no supervision
2 Requires Supervision - can perform job completely with limited supervision
1 Not Mastered - requires instruction and close supervision
N No Exposure - no experience or knowledge in this area

3	2	1	N	**A. Working With Plans**
				1. Read and create a simple construction drawing
				2. Develop a plan of procedure and a bill of materials for a construction project
				Other: ______________________
				______________________

3	2	1	N	**B. Farmstead Planning**
				1. Evaluate a site for a home
				2. Arrange a farmstead
				3. Describe characteristics of disposal systems for managing livestock manure
				Other: ______________________
				______________________

3	2	1	N	**C. Building Construction**
	▨	▨	▨	1. Describe safety practices associated with building construction
				2. Identify types and designs of buildings and their methods of construction
				3. Identify and select building materials
				4. Identify the uses of different fasteners and fastening systems
				5. Describe how to construct a floor and subfloor
				6. Describe the purpose of walls, types of walls, supports, and siding used in agricultural buildings
				7. Select a roof support system
				8. Select roofing materials

3	2	1	N	**C. Building Construction (continued)**
				9. Identify factors affecting the heating, cooling, and ventilation of agricultural structures
				Other: ______________________
				______________________

3	2	1	N	**D. Concrete**
	▨	▨	▨	1. Discuss safety in working with concrete
				2. Identify factors that affect the quality of fresh concrete
				3. Identify site preparation requirements
				4. Describe the procedure for preparing to pour a concrete slab
				5. Explain the procedure for ordering, pouring, and finishing concrete
				6. Identify factors affecting the quality of cured concrete
				7. Describe the procedure for pouring a concrete wall
				Other: ______________________
				______________________

3	2	1	N	**E. Electricity**
	▨	▨	▨	1. Identify the dangers and safety practices associated with electrical work
				2. Identify the terms associated with electrical work
				3. Match types and sizes of wire and their uses

3	2	1	N	**E. Electricity (continued)**
				4. Identify the importance of grounding and GFCI protection
				5. Locate lights, outlets, and switches, and identify circuit protection needs
				6. Identify the symbols used in agricultural wiring plans
				7. Describe practices for running wire to an agricultural structure and wiring within the building safely
				8. Identify procedures for connecting the drop wires and branch circuit wires to the SEP
				9. Describe how to run wiring from the SEP to a junction box, lights, and receptacles
				10. Calculate cost and electrical power using Ohm's Law
				11. Describe procedures for planning and installing lightning protection
				12. Identify problems in electrical systems
				Other: ______________________
				______________________

BEST COPY AVAILABLE

3	2	1	N	**F. Plumbing**
				1. Calculate how much water is needed for a farmstead
	■	■	■	2. Discuss safety practices for plumbing
				3. Identify pipe types and determine size requirements
				4. Measure, cut, and connect pipes and tubing
				5. Identify methods of protecting water pipes against freezing
				Other: ____________________
				____________________

3	2	1	N	**G. Fencing**
	■	■	■	1. Discuss the terminology, dangers, and safety practices associated with building fences
				2. Describe how to set and brace wood and steel posts
				3. Describe techniques for building barbed and woven wire fences
				4. Describe techniques for building high tensile and electric fences
				5. Identify fence mending techniques
				Other: ____________________
				____________________

Student Names															
															UNIT I - WORKING WITH PLANS
															1. Read and create a simple construction drawing.
															2. Develop a plan of procedure and a bill of materials for a construction project.
															UNIT II - FARMSTEAD PLANNING
															1. Evaluate a site for a home.
															2. Arrange a farmstead.
															3. Describe characteristics of disposal systems for managing livestock manure.
															UNIT III - BUILDING CONSTRUCTION
															1. Describe safety practices associated with building construction.
															2. Identify types and designs of buildings and their methods of construction.
															3. Identify and select building materials.
															4. Identify the uses of different fasteners and fastening systems.
															5. Describe how to construct a floor and subfloor.
															6. Describe the purposes of walls, types of walls, supports, and siding used in agricultural buildings.
															7. Select a roof support system.
															8. Select roofing materials.
															9. Identify factors affecting the heating, cooling, and ventilation of agricultural structures.
															UNIT IV - CONCRETE
															1. Discuss safety in working with concrete.
															2. Identify factors that affect the quality of fresh concrete.
															3. Identify site preparation requirements.
															4. Describe the procedure for preparing to pour a concrete slab.
															5. Explain the procedure for ordering, pouring, and finishing concrete.

Student Names

6. Identify factors affecting the quality of cured concrete.
7. Describe the procedure for pouring a concrete wall.

UNIT V - ELECTRICITY

1. Identify the dangers and safety practices associated with electrical work.
2. Identify the terms associated with electrical work.
3. Match types and sizes of wire with their uses.
4. Identify the importance of grounding and GFCI protection.
5. Locate lights, outlets, and switches, and identify circuit protection needs.
6. Identify the symbols used in agricultural wiring plans.
7. Describe practices for running wire to an agricultural structure and wiring within the building safely.
8. Identify procedures for connecting the drop wires and branch circuit wires to the SEP.
9. Describe how to run wiring from the SEP to a junction box, lights, and receptacles.
10. Calculate cost and electrical power using Ohm's Law.
11. Describe procedures for planning and installing lightning protection.
12. Identify problems in electrical systems.

UNIT VI - PLUMBING

1. Calculate how much water is needed for a farmstead.
2. Discuss safety practices for plumbing.
3. Identify pipe types and determine size requirements.
4. Measure, cut, and connect pipes and tubing.

Student Names															
															5. Identify methods of protecting water pipes against freezing.
															UNIT VII -FENCING
															1. Discuss the terminology, dangers, and safety practices associated with building fences.
															2. Describe how to set and brace wood and steel posts.
															3. Describe techniques for building barbed and woven wire fences.
															4. Describe techniques for building high tensile and electric fences.
															5. Identify fence mending techniques.

UNIT I - WORKING WITH PLANS

Lesson 1: Preparing a Plan

Competency/Objective: Read and create a simple construction drawing.

Study Questions

1. **Why is having a good plan important?**
2. **What are the steps in making a good plan?**
3. **What is the definition of scale?**
4. **How is scale used in the drawing and interpreting of plans?**
5. **What are the common symbols and elements of a plan?**
6. **What is computer-aided drafting (CAD)?**

References

1. Agricultural Structures *(Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit I.
2. Transparency Masters
    a) TM 1.1: Architect's Scale
    b) TM 1.2: Labeling
    c) TM 1.3: Symbols
    d) TM 1.4: Lines
    e) TM 1.5: Elevation Drawings
3. Activity Sheets
    a) AS 1.1: Reading a Plan
    b) AS 1.2: Drawing a Plan (Instructor)
    c) AS 1.2: Drawing a Plan (Student)

Lesson 1: Preparing a Plan

TEACHING PROCEDURES

A. *Introduction*

A variety of structures are used in agriculture, and they all start with a plan. This lesson will increase understanding of plans by providing an opportunity to produce a simple construction drawing. Although professionally drawn plans for nearly any conceivable project are available at a reasonable cost, the production of a plan will give a much better understanding of the information plans convey.

B. *Motivation*

Begin the lesson by writing the statement "Prior planning prevents poor performance" on the board. Ask the students for feedback about why planning is important and list their points on the board. To prompt discussion, suggest some elements to consider when planning, such as intended use, size, and style. Discuss with the students why prior planning is important, pointing out that changes to the plan can be easily accomplished, in comparison to changes made to a structure after it has been completed. Explain that a plan is a collection of information that builders use to know what a structure should look like and how to proceed.

C. *Assignment*

D. *Supervised Study*

E. *Discussion*

1. Ask students why planning is important. Reemphasize the points made in the motivation. Explain that in its final form the plan will contain all the information needed to complete the structure. Explain that the objective of a simple construction plan is to convey an overall understanding of the size and shape of the structure.

   Why is having a good plan important?

   a) Provides for a useable structure that serves its intended purpose
   b) Provides an opportunity to design the structure to meet specific needs
   c) Saves time and money
   d) Allows an individual to avoid the difficulties associated with situations caused by a lack of careful forethought

2. Ask students to list the steps in making a plan.

   What are the steps in making a good plan?

   a) Determine and define needs.
   b) Determine the size of the structure.
   c) Choose the style of the structure.
   d) Consider other factors.
      1) Material resources available
      2) Cost factors and constraints
      3) Building and fire codes
      4) Zoning laws
      5) Insurance and/or financial stipulations
      6) Safety considerations for specific structures

        7) Utility and service access
        8) Cleaning requirements
        9) Heating and cooling requirements

3. Ask students to define scale.

What is the definition of scale?

a) Scale is a proportion between two sets of dimensions.
b) For plans, scale indicates an adjustment in the size of a drawing that reflects the size of the object being drawn.

4. Ask students to describe how they would choose a particular scale for a structure. Explain why different scales are used, pointing out that the larger the actual structure, the smaller the scale needs to be to fit on a standard page. Make sure the students understand that whatever size the scale is, it represents one foot of the actual structure. Show students the architect's scale pictured in TM 1.1.

How is scale used in the drawing and interpreting of plans?

a) For basic plan drawing, a picture sized to fit on drawing paper is done to scale to represent the actual size of the structure being built. A system for reducing the actual size mathematically has been devised to allow for easy drawing and interpretation.
b) Scale may be drawn by using a triangular architect's scale; it combines the eleven commonly used scales on one tool.
c) A regular ruler may also be used to draw a simple plan to scale.

5. Ask the class what the elements of a plan are. Use TM 1.2 to explain where and what information will be required on drawings. Show students TM 1.3. Explain that symbols are used in drawings as a convenience to represent different items contained in a drawing. Use TM 1.4 to illustrate the types of lines found on plans. Discuss the use of elevation drawings, showing the class TM 1.5. Have students complete AS 1.1.

What are the common symbols and elements of a plan?

a) Elements are the different parts of the drawing that convey information or enhance the information provided.
    1) Information in the blocks provided in the title box
        (a) Name of the person drawing the plan
        (b) Title of the project
        (c) Date
        (d) Scale
    2) Symbols - pictorial representations of information that are included on the drawing
        (a) Symbols that may be subject to the same scale as the rest of the drawing and show the location of these parts of the structure
            (1) Doors
            (2) Windows
        (b) Symbols representative of where devices or appliances are to be located
            (1) Electrical fixtures
            (2) Plumbing fixtures
        (c) Symbols for the type or grade of materials used
            (1) Concrete
            (2) Steel
            (3) Wood
    3) Lines
        (a) Border line - dark line around the perimeter of the drawing paper
        (b) Object line - used to draw the object

    - (c) Hidden line - represents material that is under other material
    - (d) Extension line - used for placing dimensions on drawings
    - (e) Dimension line - shows the size of an object
    - (f) Break line - represents an area in the structure where a section has been removed
    - (g) Cutting plane - shows where a section has been removed with arrows showing the direction from which it was taken
    - (h) Center line - shows the centers of holes and round shapes
  - b) Elevation drawings are orthographic projections of a structure as viewed from different perspectives, most commonly the top, front, and one or both sides.

6. Ask students if they know what CAD (computer-aided drafting or design) means. Emphasize that plans drawn using CAD are only as good as the drafter's skill and talent allow. CAD cannot replace the drafter's creativity; it only makes it easier to express. Have students begin AS 1.2. Evaluate the school's resources. If students have access to enough terminals with CAD capabilities and either are knowledgeable about CAD or can be taught the basics in the time allotted, using CAD is an excellent choice. If CAD cannot be used, students may simply draw the structure described in the activity by hand.

   What is computer-aided drafting (CAD)?

   - a) Computer-aided drafting or design, called CAD, is a system consisting of a computer and specially designed software that does the actual drawing of plans.
   - b) CAD is now the industry standard for drafting.
   - c) The four main benefits of CAD over conventional hand drafting are speed, quality, ease of making changes, and communication.

F. *Other Activities*

Have each student produce a simple construction drawing for a structure of his or her choice.

G. *Conclusion*

Having a good plan is essential to producing a good structure. Developing the plan involves considering the intended use, size, and style of the structure. After these decisions have been made, a simple construction drawing with at least three elevations is created either by hand or with CAD, using an appropriate scale and elements of the drawing to represent the structure on paper.

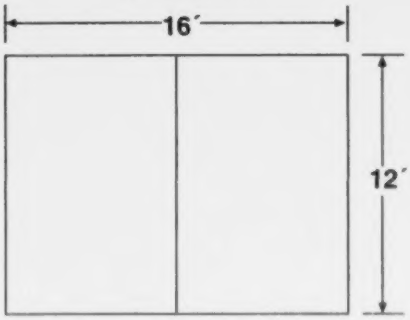
H. *Answers to Activity Sheets*

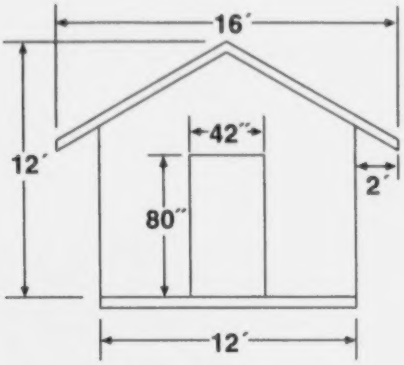
AS 1.1

1. 33 feet
2. 4 posts
3. 4 feet
4. 6 posts
5. Three
6. Five
7. Four
8. Single pole and three way switches
9. Nine, including the overhead lighting for the bench
10. Door switch

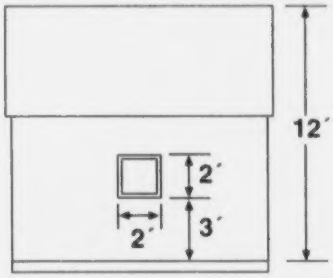
AS 1.2

Top Elevation





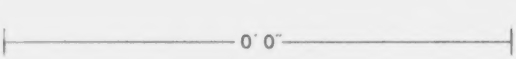
Front Elevation



Side Elevation

I. ***Answers to Evaluation***

1. b
2. b
3. c
4. Scale can be defined as a proportion between two sets of dimensions.
5. Computer-aided drafting or design is a system consisting of a computer and specially designed software that does the actual drawing of plans.
6. Answers may include any two of the following: A good plan provides for a useable structure that serves its intended purpose, provides an opportunity to design the structure to meet specific needs, saves time and money, and allows an individual to avoid the difficulties associated with situations caused by a lack of careful forethought.
7. The four steps are as follows: determine and define needs, determine the size of the structure, choose the style of the structure, and consider other factors.
8. Border line
9. Dimension line



10. Object line

11. Answers will vary.

12. Students should draw a rectangle measuring 1¾ inches by 3¾ inches.

UNIT I - WORKING WITH PLANS

Lesson 1: Preparing a Plan

Name ______________________________

Date ______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Symbols are:
   a. A plan of a structure.
   b. Pictorial representations of information placed on a plan.
   c. Three views drawn to represent a structure.
   d. Lines used to represent a structure.

2. Which of the following is not found on plan drawings?
   a. Dimension lines
   b. Tie lines
   c. Border lines
   d. Hidden lines

3. Elevation drawings are:
   a. The same as blueprints.
   b. Used to build models.
   c. Produced in more than one view.
   d. Drawings showing the height of a structure.

Complete the following short answer questions.

4. What is scale?

5. What does CAD mean? What is it?

6. What are two reasons why having a good plan is important when building a structure?
   a.

   b.

7. What are the four main steps in forming a good plan for a structure?

   a.

   b.

   c.

   d.

For each of the lines listed below, draw an example of the line beside its name.

8. Border line

9. Dimension line

10. Object line

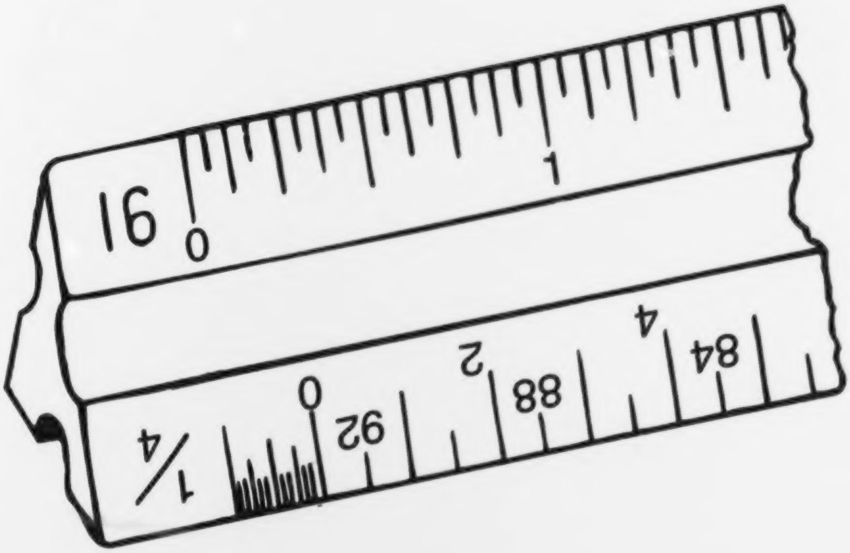
Sketch three elevation drawings (front, side, and top) for a dog house in the space below.

11.

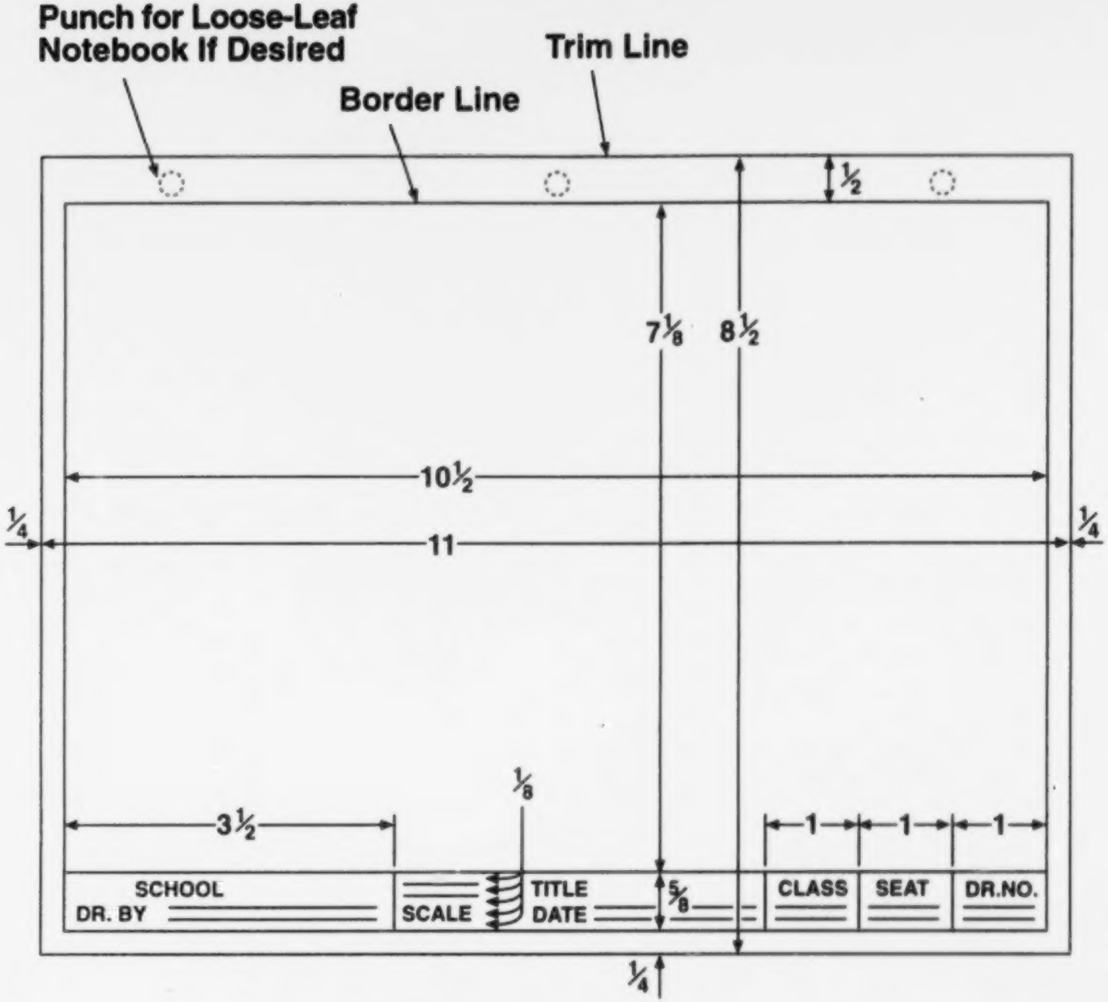
In the space provided below, use a ruler to draw a rectangle using the following scale: ¾ inch = 15 feet. The sides of the rectangle should equal 35 feet; the top and bottom of the rectangle should equal 75 feet.

12.

Architect's Scale

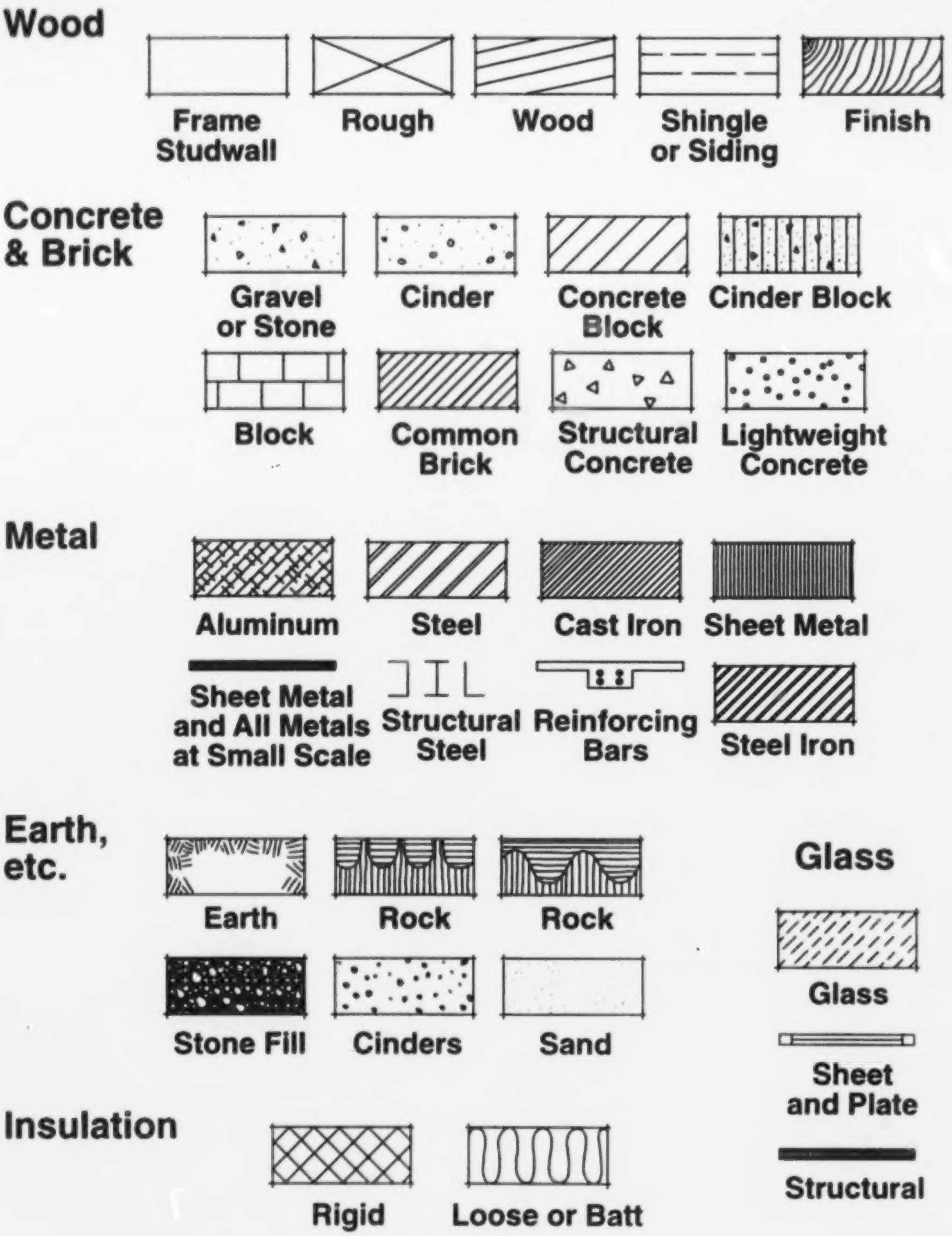

16
0
1
1/4
0
92
2
88
4
84

Labeling

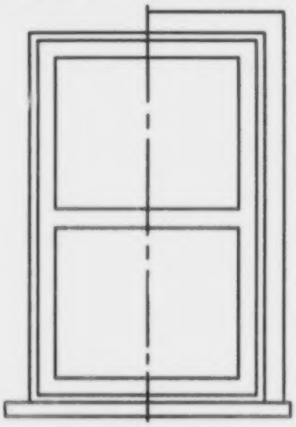

Punch for Loose-Leaf Notebook If Desired
Trim Line
Border Line
½
7⅛
8½
10½
¼
11
¼
⅛
3½
1
1
1
SCHOOL
DR. BY
SCALE
TITLE
DATE
⅝
CLASS
SEAT
DR.NO.
¼

TM 1.2

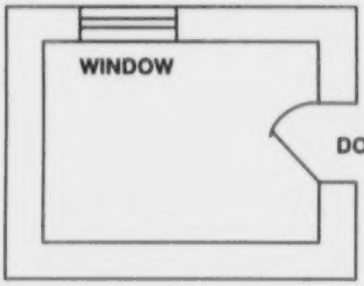
Symbols


Wood
Frame Studwall
Rough
Wood
Shingle or Siding
Finish
Concrete & Brick
Gravel or Stone
Cinder
Concrete Block
Cinder Block
Block
Common Brick
Structural Concrete
Lightweight Concrete
Metal
Aluminum
Steel
Cast Iron
Sheet Metal
Sheet Metal and All Metals at Small Scale
Structural Steel
Reinforcing Bars
Steel Iron
Earth, etc.
Earth
Rock
Rock
Stone Fill
Cinders
Sand
Glass
Glass
Sheet and Plate
Structural
Insulation
Rigid
Loose or Batt

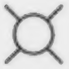
Windows in Elevations



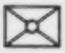
DOUBLE HUNG


WINDOW
DOOR

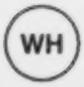
Plumbing Symbols



SHOWER DRAIN

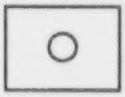


FLOOR DRAIN



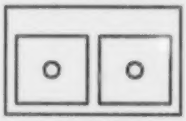
HOT WATER TANK

SINGLE SINK

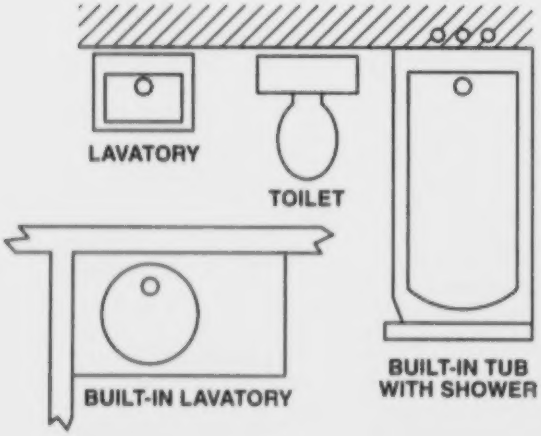


18 x 24

DOUBLE SINK



21 x 32


LAVATORY
TOILET
BUILT-IN LAVATORY
BUILT-IN TUB WITH SHOWER

Electrical Symbols

SWITCH OUTLETS

S - SINGLE POLE SWITCH
S_2 - DOUBLE POLE SWITCH
S_3 - THREE WAY SWITCH
S_4 - FOUR WAY SWITCH
S_D - AUTOMATIC DOOR SWITCH
S_{cb} - CIRCUIT BREAKER

CONVENIENCE OUTLETS

⊖ DUPLEX OUTLET
⊖ WP WEATHERPROOF
⊜ RANGE OUTLET
◬ SPECIAL PURPOSE

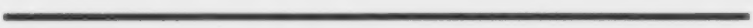
■ LIGHTING PANEL
▨ POWER PANEL
Ⓣ POWER TRANSFORMER
⊡ PUSH BUTTON
▲ TELEPHONE

GENERAL OUTLETS

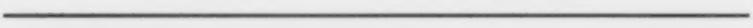
CEILING	WALL	
○	—○	OUTLET DROP CORD
Ⓢ	—Ⓢ	PULL SWITCH
Ⓙ	—Ⓙ	JUNCTION BOX

TM 1.4

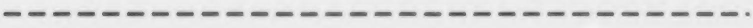
Lines



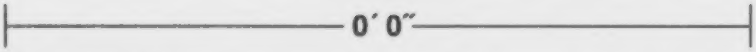
Border



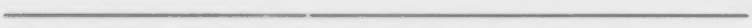
Object



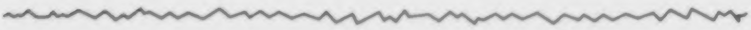
Hidden



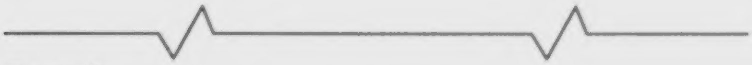
Dimension



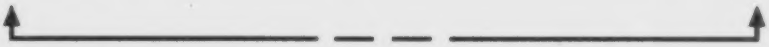
Extension



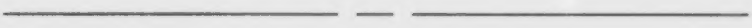
Break



Break



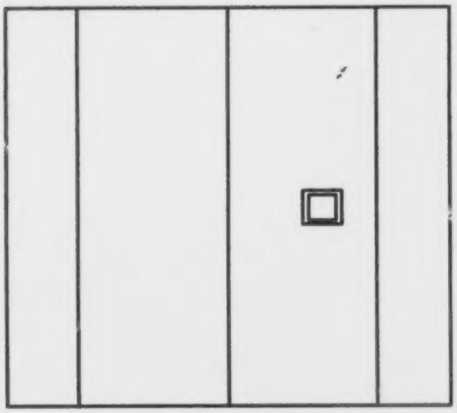
Cutting Plane



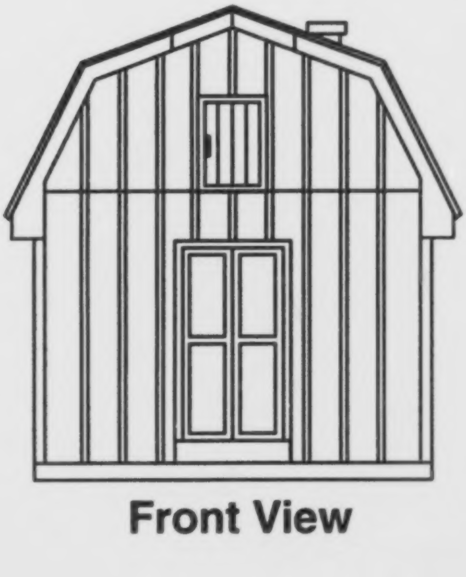
Center Line

TM 1.5

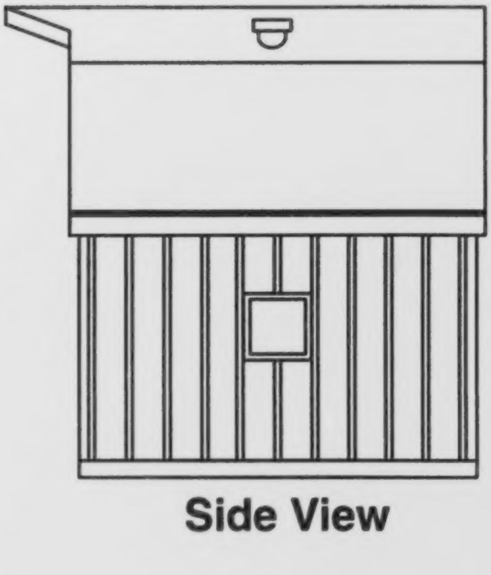
Elevation Drawings



Top View



Front View



Side View

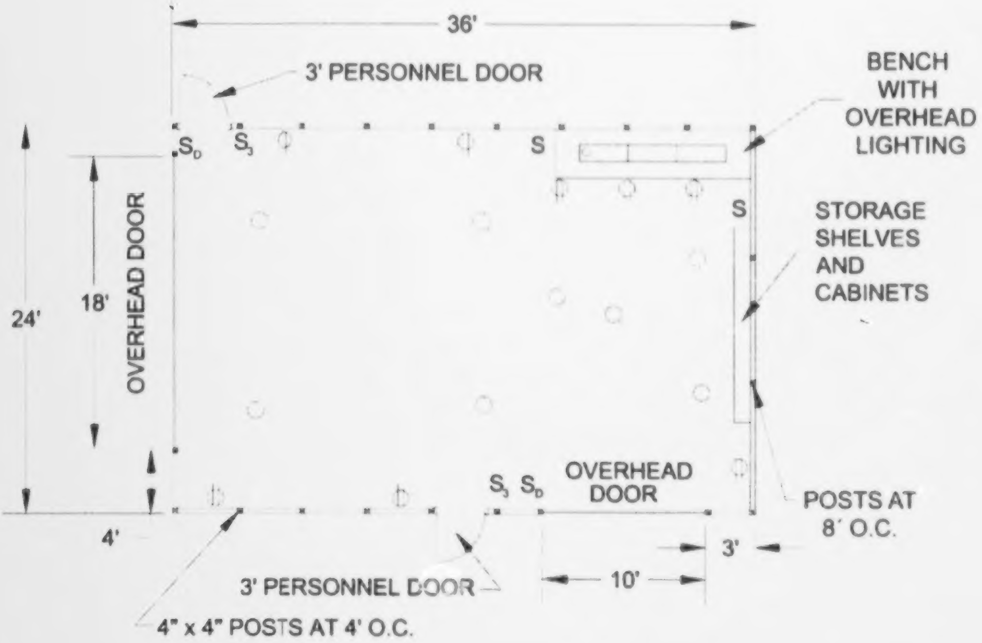
Lesson 1: Preparing a Plan

Name ______________________________

Reading a Plan

Objective: Read a simple construction plan.

Using the plan for a post frame repair shop, answer the questions.


36'
3' PERSONNEL DOOR
BENCH WITH OVERHEAD LIGHTING
STORAGE SHELVES AND CABINETS
24'
18'
OVERHEAD DOOR
S
S
S_D
S_3
S_3
S_D
OVERHEAD DOOR
POSTS AT 8' O.C.
4'
3'
10'
3' PERSONNEL DOOR
4" x 4" POSTS AT 4' O.C.

1. What is the length of the unbroken wall along the side with only a personnel door?

2. How many posts form the wall with no doors?

3. How long is the wall between the 10-foot overhead door and the personnel door?

4. How many posts could be removed from the building if 8-foot on center post spacing is used for the entire building?

5. How many duplex outlets are found along the work bench?

6. How many duplex outlets are found in the rest of the building?

7. How many light switches are found in the building?

8. What different types of light switches are used?

9. How many ceiling lighting outlets are included in the structure?

10. What does the symbol S_D mean?

Lesson 1: Preparing a Plan

Drawing a Plan

Objective: Draw a simple construction plan.

Materials and Equipment:

Computer with CAD software and printer (if possible)
Paper, either plain white copy paper or high rag content drawing paper (if professional hand drawing instruments are available)
No. 2 lead pencil
Ruler or architect's scale

NOTE: Professionals use several pencils with lead in a variety of hardnesses to produce exact results. A regular No. 2 pencil can be used but must be utilized with care to produce acceptable results.

Procedure:

For this activity, draw a plan for a storage building with a gable roof having two sloping sides that meet at the ridge and a floor space of 12 feet by 12 feet. The walls will be 8 feet in height on the sides, and the height from the floor to ridge will be 12 feet. The overhang, the part of a roof that extends past the walls of a structure, is to be 2 feet from the walls. The right and left side of the building should each have a window that is 2 feet by 2 feet. The windows should be centered in the side of the building with the bottom of the window 3 feet from the floor of the structure. The door should be 42 inches wide by 80 inches tall and centered in the front of the building.

1. Before assigning the activity, determine what drafting experience the students possess. Knowledge will vary, but ideally the students will have had some involvement in previous classes such as industrial technology. If students do not have much experience, working through the activity with them may be necessary. Review the following information if needed:

    - How scale is used in drawing
    - Using a separate page for each elevation drawing
    - Using border lines around the edges of the paper
    - Centering the drawings on the page
    - Using dimension lines to show the overall dimensions of the structure

2. The whole process is much less involved for the students using CAD. They will complete a plan for the same structure, but using templates and automation. If using CAD is possible, your students will need access to a computer system with CAD capabilities and a suitable printer.

3. If the plans are to be hand drawn, students will need a suitable desktop or table, although drafting tables would be better. Triangular architect's scales may be used if they are available.

    Professional drawing instruments such as Bow pens, pencils and dividers, triangles, T-squares, and an assortment of pencils and inks may be available to some students. If so, excellent results may be achieved using professional quality high rag content drawing paper.

Lesson 1: Preparing a Plan Name ____________________________

Drawing a Plan

Objective: Draw a simple construction plan.

Materials and Equipment:

Computer with CAD software and printer (if possible)
Paper
No. 2 lead pencil
Ruler or architect's scale

NOTE: Professionals use several pencils with lead in a variety of hardnesses to produce exact results. A regular No. 2 pencil can be used but must be utilized with care to produce acceptable results.

Procedure:

For this activity, draw a plan for a storage building with a gable roof having two sloping sides that meet at the ridge and a floor space of 12 feet by 12 feet. The walls will be 8 feet in height on the sides and the height from the floor to ridge will be 12 feet. The overhang, the part of a roof that extends past the walls of a structure, is to be 2 feet from the walls. The right and left side of the building should each have a window that is 2 feet by 2 feet. The windows should be centered in the side of the building with the bottom of the window 3 feet from the floor of the structure. The door should be 42 inches wide by 80 inches tall and centered in the front of the building.

1. If you are drawing by hand, prepare three sheets of paper, one for each of the different elevation drawings. Neatly include the following information on each sheet in a title box: your name, title of the project, date, and scale. A sample page showing labeling is included with this activity sheet.
2. Choose a scale for the drawing that will allow it to fit in the area provided by the paper.
3. Center your drawings in the area inside the border lines. Use object lines to draw the structure. Windows and doors are to be represented by the appropriate symbols where they are to be located.
4. Dimension lines are to be used to define the measurements of the structure and/or the exact size of elements in the structure. Use dimension lines to show width, length, and height as well as the dimensions of windows and doors and the amount of overhang. These lines are to be clean and precise.
5. Draw the front elevation.
6. Draw the side elevation.
7. Draw the top elevation.

UNIT I - WORKING WITH PLANS

Lesson 2: Understanding a Plan of Procedure

Competency/Objective: Develop a plan of procedure and a bill of materials for a construction project.

Study Questions

1. **What are the steps in making a plan of procedure?**
2. **What is the importance of a bill of materials?**
3. **What is the difference between a cutting bill of materials and a purchasing bill of materials?**

References

1. *Agriculture Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit I.
2. Activity Sheet
    a) AS 2.1: Preparing a Plan of Procedure

Lesson 2: Understanding a Plan of Procedure

TEACHING PROCEDURES

A. ***Review***

Having developed an understanding of basic construction plans in Lesson 1, it is now time to explore the planning process. A plan of procedure for a construction project involves determining the order in which to proceed as well as developing lists of the materials needed.

B. ***Motivation***

Discuss the advantages of having and following a good plan of procedure. Describe a scenario involving pouring concrete before plumbing lines have been installed. This example creates a very good visual image of a situation that could have been avoided with proper planning.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Ask students to list the steps in forming a plan of procedure. Discuss the four steps in developing a plan.

What are the steps in making a plan of procedure?

a) A plan of procedure is the order in which everything concerning the eventual completion of a planned project is identified, listed, and then arranged in a logical order from the first step to the last step.

b) Developing a plan of procedure involves four steps.
   1) The first step in developing a plan of procedure is identifying every factor that may affect the project and then arranging all the identified elements in a logical order.
   2) From the information thus far assembled, a decision is made about the type and grade of materials that is appropriate for the project.
   3) A list of materials required will need to be developed from the information assembled so far and by studying the plan drawings.
   4) Materials must be purchased, cut, and assembled in a logical order.

2. Discuss the description of a bill of materials. Ask students why developing a material list is important.

What is the importance of a bill of materials?

a) A bill of materials is a list of all the components needed to complete a proposed project, identifying the amount, size, and kind of materials needed. These lists are necessary for purchasing the correct amount of materials and for obtaining cost estimates.

3. Discuss a cutting bill of materials and a purchasing bill of materials, and explain the difference between the two. Have students complete AS 2.1.

What is the difference between a cutting bill of materials and a purchasing bill of materials?

a) Many materials used in agricultural structures, such as plumbing supplies and lumber, are available for purchase in standard lengths and dimensions; as a result, more material will be purchased than used in the project, and the materials are then cut to the exact dimensions needed during construction.

b) Cutting bill of materials
   1) This list is generally developed first to prevent waste when purchasing materials.
   2) It is a list of the materials needed to assemble the project, in their required dimensions.

c) Purchasing bill of materials
   1) This list is developed from the information accumulated to this point.
   2) The list will include not just the materials identified from the cutting list in their standard sizes, but everything needed to construct the project, such as fasteners, hinges, wire, etc..

F. ***Other Activities***

Have students develop a project for an agricultural structure of their choice. They should produce a plan of procedure, including a cutting bill of materials and purchasing bill of materials.

G. ***Conclusion***

This lesson provides an understanding and appreciation of a plan of procedure. It also provides a working knowledge of how to apply the four-step procedure to develop a plan for an agricultural structure.

H. ***Answers to Activity Sheet***

1. Identify all the steps necessary to complete the project. Decide what materials should be used to construct the project. List the materials needed to complete the project, preparing a cutting and a purchasing bill of materials. Purchase the materials according to the purchasing bill of materials, make the cuts according to the cutting bill of materials, and assemble the project.

2. Top - Four 2" × 6" boards 4 feet in length and sixteen 3-inch wood screws
   Side braces - Two 2" × 6" boards 18 inches in length, two 2" × 6" boards 39 inches in length, and 24 3-inch wood screws
   Legs - Four 2" × 4" boards 2 feet in length

3. Eight 4-foot 2" × 6" boards
   Two 18-inch 2" × 6" boards
   Two 36-inch 2" × 6" boards
   Four 2-foot 2" × 4" boards

4. Four 8-foot 2" × 6" boards
   One 10-foot 2" × 6"
   Forty 3-inch wood screws

I. ***Answers to Evaluation***

1. c
2. b
3. d

4. The steps are: identify every factor that may affect the project and then arrange all the identified elements in a logical order, decide what type and grade of materials will be used to construct the project, develop lists of materials required, and finally purchase, cut, and assemble materials.

5. A cutting bill of materials is a list of the materials needed to assemble the project in their required dimensions. A purchasing bill of materials is not just the materials identified from the cutting list in their standard sizes, but everything needed to construct the project.

6. Usually the cutting bill of materials needs to be developed first to prevent waste when purchasing materials.

7. The bill of materials is important because it is necessary for purchasing the correct amount of materials and for obtaining cost estimates.

Name ______________________________

Date ______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. A bill of materials consists of:

   a. The same information as the cutting bill of materials.
   b. The same information as a purchase order.
   c. A list of all materials needed for a project.
   d. A list of the materials that have been purchased.

2. The cutting bill of materials is:

   a. The same as the purchasing bill of materials.
   b. A list of the materials for the project in required dimensions.
   c. Not important until after materials have been purchased.
   d. Determined after project completion.

3. A purchasing bill of materials:

   a. Is the same as the cutting list.
   b. Cannot be determined until project completion.
   c. Is a list of lumber to be purchased.
   d. Is a list of all materials to be purchased.

Complete the following short answer questions.

4. What are the steps in forming a plan of procedure?

5. What is the difference between a purchasing and a cutting bill of materials?

6. Would the purchasing bill of materials be prepared before or after the cutting bill of materials? Explain your answer.

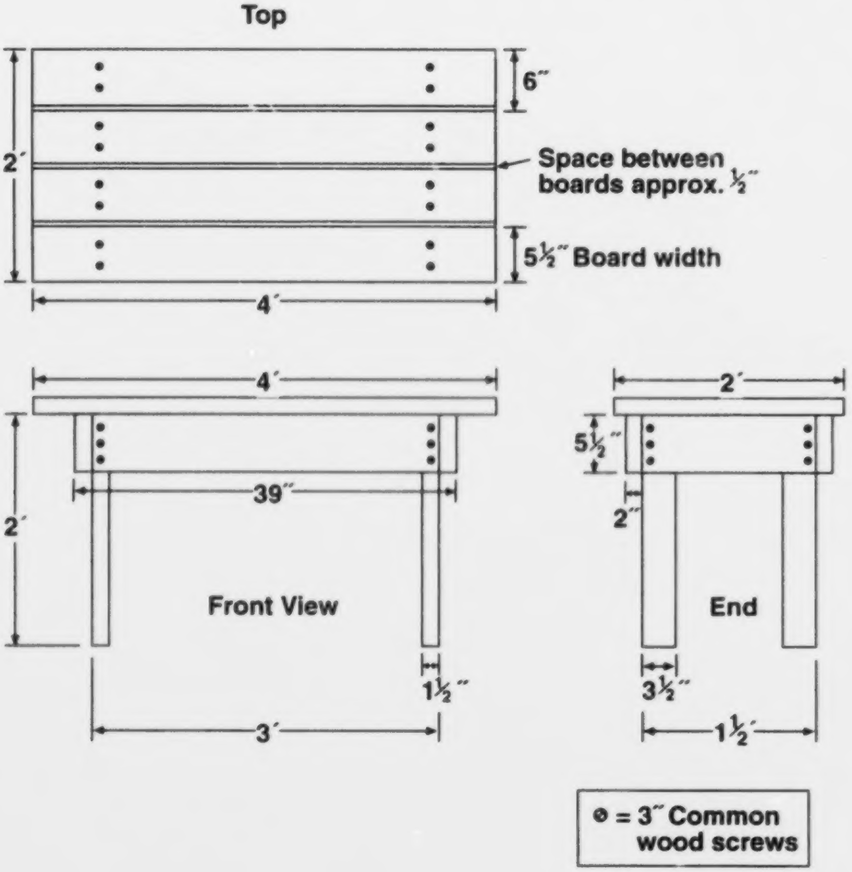
7. Why is making a bill of materials important?

Lesson 2: Understanding a Plan of Procedure Name ______________________

Preparing a Plan of Procedure

Objective: Formulate a plan of procedure, including a cutting and a purchasing bill of materials.

Three elevation drawings of a pine workbench complete with dimension lines are shown below. Look at the three drawings of the workbench. Evaluate the drawings carefully. Then, answer the following questions.


Top
6"
2'
Space between boards approx. ½"
5½" Board width
4'
4'
39"
2'
Front View
1½"
3'
2'
5½"
2"
End
3½"
1½'
● = 3" Common wood screws

1. What would be the steps in a plan of procedure for this project?

2. In the space below, list all the materials needed for the project.

3. Use the information from the list to develop a cutting bill of materials.

4. Develop a purchasing bill of materials. (Hint: Dimensional lumber from retailers most commonly starts at 8 feet and increases in length in 2-foot increments.)

UNIT II - HOME AND FARMSTEAD PLANNING

Lesson 1: Home Site Selection

Competency/Objective: Evaluate a site for a home.

Study Questions

1. **How do soil and water conditions affect selection of a site?**
2. **How does topography affect planning for the home site?**
3. **How does wind affect planning?**
4. **How do services and utilities affect selection of the site?**
5. **What is the impact of regulatory agencies on planning for the home?**
6. **How do neighbors affect planning?**
7. **What are the implications of having the home and business on the same site?**
8. **What is the importance of conducting an environmental audit on a selected site?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit II.
2. Activity Sheet
    - a) AS 1.1: Evaluating Home Sites

UNIT II - HOME AND FARMSTEAD PLANNING

Lesson 1: Home Site Selection

TEACHING PROCEDURES

A. ***Introduction***

Careful planning is involved in selecting a site for constructing a new home. Building in rural locations poses unique considerations. In order to have the best possible home when construction is completed, careful thought must be given to the selection of a home site.

B. ***Motivation***

Ask students to imagine that the class will be building a project on a particular piece of ground next to the school. Students should be asked if it will matter where the building is built on that land. The class discussion can be centered on those factors that might influence the location of the construction project.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Discuss what effect soil conditions and surface and subsurface water have on the selection of a site.

   How do soil and water conditions affect selection of a site?

   a) Soil conditions
      1) The bedrock depth and soil type will affect foundation design decisions.
      2) A test should be done to determine the depth of bedrock formations or the underlying soil conditions at possible sites.
   b) Surface and subsurface water
      1) Any site with surface and subsurface water for more than half the year should be avoided if possible.
      2) A building site will be easier to work with and on if the location selected does not have subsurface water.
         (a) Makes concrete work more difficult by increasing the moisture level in the concrete
         (b) Makes sealing the building difficult, which will lead to water in the basement or crawl space
         (c) Leads to mold, mildew, or rot in wood buildings.
      3) If an entire plot has subsurface water, a drainage system may possibly be installed to remove the excess water.

2. Ask students to consider what the effect would be of building a home on top of a hill. Then ask them to consider what a home built in the bottom of a valley would be like. Would the homes have the same conditions?

   How does topography affect planning for the home site?

   a) Topography - the relative positions and elevations of the natural or man-made features of an area that determine the surface configuration of the land
   b) Hillside construction

        1) Construction will have higher costs because the need for retaining walls, grading, fill material, and general site preparation is greater in comparison to a flat site.
        2) Considerable amounts of soil may need to be either removed or brought onto the site.
        3) This process will require additional advance planning in securing a place to deposit excavated dirt or finding a source for dirt or proper fill material.
    c) Water runoff
        1) Building a house at the bottom of a hill means that water will run down toward the house, possibly causing flooding or sub-irrigation problems.
        2) A home site should generally be located on a higher elevation than livestock facilities or crop ground where many chemicals are used in order to allow the water runoff to flow away from the site.
    d) Amount of wind that strikes the home
        1) Homes built on hilltops or knolls generally receive more wind than those built on hillsides or at the base of hills.
        2) Natural growing trees or man-made windrows can provide protection from wind, but the topography may limit natural growth or make new trees hard to establish.
        3) Additional construction costs may be incurred to insulate and strengthen roofs and walls that are exposed to heavy prevailing winds.
    e) Possibility of expansion
        1) If an addition onto the building may some day be necessary, careful consideration should be given to the initial site chosen for the building.
        2) Room needs to be left around the building, especially on those sides where additions may be built.
    f) Building perspective, or view
        1) Building perspective is the direction a building faces in relation to the external scenery.
        2) If a scenic view is desired and offered by a certain direction, the view must be considered in laying out the building.

3. Another consideration in selecting a building site for a house is wind. Discuss the effect of wind on planning for the construction of a house.

How does wind affect planning?

a) Main entrance - commonly located on a side of the house away from prevailing winds
b) If the door faces the direction of the prevailing winds
    1) Rain, dust, and debris may blow into the house.
    2) The wind may cause damage when the door is opened.
    3) Snow drifts can also accumulate around the door and may make it inaccessible.

4. Every new building requires certain services and utilities. Ask students to describe how services and utilities can impact the selection of a building site.

How do services and utilities affect selection of the site?

a) The distance to services and utilities should be considered because it will affect the cost of bringing them to the home.
    1) It is desirable to build as close to existing roads and utility lines as possible, especially electricity, telephone, and gas lines.
    2) If the closest access is found at one corner of the property, the home may be placed closer to that corner.
    3) The local electrical power, telephone service, and natural gas suppliers may be contacted to determine the cost.
b) If the location of the utilities is unknown, locator services can come to the property to determine the location.

    1) Using a locator service may reveal that some of the utilities already cross the property.
    2) By planning utility access, the builder can budget for the costs of bringing the utility to the building.

c) Many rural homes make use of propane gas for heating or cooking.
    1) Tanks should be located so as not to detract from the home's appearance.
    2) They should be easily accessible for the propane supplier to refill.
    3) Propane suppliers will provide tanks, meters, and trenched-in connecting lines for an initial lease fee for their customers.
    4) Suppliers may provide footing blocks, or the home builder can pour a level concrete pad to set the tank on.
    5) Home owners are required to provide a stubbed-up exterior line that is securely capped or connected to the heating system and/or appliances.

d) Drilling a well is often necessary for rural homes.
    1) State law requires all wells used for drinking water to be drilled to at least 80 feet to prevent groundwater runoff from directly entering the system.
    2) Knowing the average depth of drilling to reach quality water prior to selecting the site may influence selection.
    3) Drilling costs are based on the number of feet drilled and the soil structure where the drilling will be done.
    4) To determine approximate drilling depth, homeowners should contact the Missouri Department of Natural Resources, Division of Geology and Land Services.

e) Several rural areas throughout the state have access to rural water districts.
    1) Water is purchased and piped from a nearby town or city's reservoir or well system.
    2) A homeowner can hook into this system for an initial fee and then purchase water based on usage on a monthly basis.
    3) Using a rural water district may be more cost efficient if the distance to the connection is fairly close and if the topography presents no major obstacles.

f) If sewer service is not available, the builder will need to arrange for a private sewage disposal system to be constructed.
    1) A large area of land and suitable soil is necessary to prevent contamination of surface water and wells.
    2) Septic systems should be located away from home and building sites.
    3) Local or county sewer regulations should be consulted before building to determine if a site is acceptable.
    4) Many counties will not allow a septic tank or sewer field to be placed within a certain distance of rivers or ponds.

g) Access to the site for concrete, lumber, and other material deliveries is important.
    1) Consideration should be given to where the roads currently are and where they will need to be built on the property.
    2) Roads and room for turning around should be provided.
    3) Time should be taken to consider where a lawn or any other landscaping will be prior to laying out the roads.
    4) Geomat is commonly placed on the ground to provide traction, if the site is wet and muddy.
    5) Bridges may need to be added to allow access.

5. Ask students what agencies may have control over where and how a house is built.

What is the impact of regulatory agencies on planning for the home?

a) Fire codes and local building codes
    1) Fire codes may specify the distance from other buildings necessary to provide fire trucks and other emergency equipment access to the site.
    2) Common building codes include regulations for the reinforcement of concrete structures, service access, and utility access.

    3) An inspection is often required prior to beginning the project to make sure the building will be constructed according to code.
    4) For information about the codes for a particular area, the local building inspector or county commission can be contacted.

  b) Zoning laws
    1) Many communities have zoning laws that prohibit the construction of private homes in areas that have been zoned for commercial development.
    2) The local zoning commission, building inspector, or assessor can usually identify local zoning laws.

  c) County board of commissioners
    1) In a rural area, builders may only need to obtain permission for construction from a county board of commissioners.
    2) The amount of regulation will depend on the local area.
      (a) In some places, sewer fields must be approved prior to construction, generally by a local or county sanitation board.
      (b) Zoning laws have also become much more common in many agricultural areas.

6. Ask students how close their own neighbors are, and if problems with neighbors have ever occurred. Discuss the effects of building more houses in rural areas.

How do neighbors affect planning?

a) Some landowners choose to build the home as far as possible from other neighbors to obtain greater privacy.
b) If neighbors are also relatives, some home builders may select a site that is relatively close to allow for more family interaction and promote a greater sense of security.

7. Ask students who live on farms what they think are advantages and/or disadvantages of having a home on a farmstead. Discuss factors to consider when deciding whether to have a home as part of a farmstead.

What are the implications of having the home and business on the same site?

a) Possible sale of the home at a later time
  1) Many owners choose to sell an existing home to finance the construction of a new one.
  2) If the home is in the center of some type of business site, it may be difficult or impractical to sell.
  3) If the home is located on the edge of the property separate from the business, selling the home will be easier but will require accepting new and closer neighbors.
  4) Road access to the farming or business operation may have to be added, as well as connections to services and utilities.
b) Excessive noise, traffic, or pollution
c) Potential safety problems for the residents, especially children
  1) Agricultural operations use numerous pieces of equipment that are dangerous.
  2) Many people prefer to locate the home away from more hazardous activities to help ensure the safety of children and visitors.

8. Ask students to list possible environmental issues that may affect the selection of a building site. Discuss the need to conduct an environmental audit. Have students complete AS 1.1.

What is the importance of conducting an environmental audit on a selected site?

a) Environmental audit
  1) Examines the potential building site to determine if any environmental issues will need to be addressed prior to construction

        2) Can alert home builders to a number of potential hazards and what measures can be taken to eliminate any problems
    b) Potential problems
        1) Abandoned wells, especially on old farmstead sites
            (a) Many old rock wells have been abandoned or even used to dispose of hazardous liquids.
            (b) Even modern wells have been abandoned for rural water connections.
            (c) A thorough environmental audit can help identify any abandoned wells through a study of county records of the property and a physical evaluation of the site.
        2) Identification of underground storage tanks, old landfills, or dump sites
            (a) Underground tanks may have held substances like gasoline or diesel fuel.
            (b) Landfills or dump sites could contain chemicals that are harmful to humans if they get into the drinking water.

F. *Other Activities*

Obtain information from the local zoning or planning commission concerning legal issues affecting building homes in the local area. Allow students to evaluate the regulations and determine why they exist.

G. *Conclusion*

When selecting a site for building a home, a number of issues should be considered prior to selecting the final site. These factors include topography, wind, services and utilities, regulatory agencies, neighbors, having the home and business on the same site, and environmental issues. By carefully considering these factors, prospective builders can select the ideal site that will eliminate or minimize problems later.

H. *Answers to Activity Sheets*

I. *Answers to Evaluation*

1. a
2. d
3. a
4. b

5. Answers may include any two of the following: future sale of the home; excessive noise, dust, or pollution; potential safety problems for residents, especially children, odors, fumes, dust, etc.

6. Underground tanks, abandoned wells, landfills or dump sites
7. To allow for more family interaction and promote a greater sense of security
8. Because the distance will affect the cost of bringing them to the home

9. Answers may include any two of the following: hillside construction, water runoff, amount of wind, possibility of expansion, and building perspective.

UNIT II - HOME AND FARMSTEAD PLANNING Name__________________________

Lesson 1: Home Site Selection Date___________________________

EVALUATION

Select the letter that corresponds to the best answer.

1. Which part of the house is usually considered when designing for wind?

   a. Doors
   b. Windows
   c. Chimneys
   d. Eaves

2. Many counties have limitations on how close __________________ should be located to rivers or ponds.

   a. Electricity
   b. Telephone wires
   c. Gas lines
   d. Septic fields

3. An example of an agency that might be contacted prior to selecting a site is the:

   a. Zoning commission.
   b. County clerk.
   c. Treasurer.
   d. Weed control bureau.

4. What is one effect of subsurface water on a construction site?

   a. Affects the size of the foundation
   b. Makes sealing the building difficult
   c. Limits the size of the home
   d. Makes additional dirt necessary

Complete the following short answer questions.

5. What are two factors that should be considered when building the home on the site of the business?

   a.

   b.

6. What are three potential problems an environmental audit may discover about the land under consideration for building a home?

   a.

   b.

   c.

7. Why might a builder choose to locate a home close to a neighbor who is also a relative?

8. Why should the distance to services and utilities be considered when selecting a site for a home?

9. What are two factors related to topography that will affect the selection of a site?

   a.

   b.

Lesson 1: Home Site Selection Name ____________________

Evaluating Home Sites

Objective: Evaluate home sites according to the criteria discussed in this lesson.

For this activity, select a home site found in the country, using either your own home or the home of a friend or family member. Evaluate the home site according to the criteria discussed in the lesson, noting what impact, if any, each of these factors had on the selection of the site.

Location of home site: ______________________________________

Factors	Description of the Site
Topography	
Wind	
Services and utilities	
Neighbors	
Home on business site	
Environmental issues	

In your opinion, why was the home constructed on that particular site?

UNIT II - HOME AND FARMSTEAD PLANNING

Lesson 2: Arranging a Farmstead

Competency/Objective: Arrange a farmstead.

Study Questions

1. **How does the direction of the layout affect farmstead planning?**
2. **How does topography affect farmstead planning?**
3. **How does wind affect farmstead planning?**
4. **How does the potential of the natural resources base in comparison to environmental impact affect the farmstead plan?**
5. **What is the effect of the type and size of business on farmstead planning?**
6. **How do services and utilities affect farmstead planning?**
7. **How do neighborhoods affect farmstead planning?**
8. **What is the impact of regulatory agencies on farmstead planning?**

References

1. *Agriculture Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit II.
2. Activity Sheet

   a) AS 2.1: Farmstead Planning
   b) AS 2.2: Planning a Farmstead

Lesson 2: Arranging a Farmstead

TEACHING PROCEDURES

A. ***Review***

Lesson 1 addressed factors to consider when selecting a site for a home. Preparing a farmstead plan also takes care and forethought. The variety and complexities of modern farms make a good farmstead plan a requirement for successful operation. This lesson outlines many factors that must be considered to devise a good plan. Forming a good farmstead plan also requires research and expert help. Local University Extension offices are an excellent resource for information and referrals.

B. ***Motivation***

Discuss some key factors that affect the farmstead plan. Factors for possible discussion are service area, wind, water quality and quantity, surface and watershed drainage, current and future production volume requirements, and codes and regulations.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Question the class about factors affecting the direction of farm layout and list them on the board.

   How does the direction of the layout affect farmstead planning?

   a) Farmstead planning often involves orienting activities in relation to one another and the farm's effect on surrounding areas.
      1) Structures associated with related activities, such as feed storage facilities and feed lots, should be located near one another.
      2) Noise, dust, pollution potential, and insects associated with agricultural activities must be anticipated and directed away from residential areas.
   b) Orientation of structures according to the four directions is usually done to minimize the effects or take advantage of natural elements such as sun or a prevailing wind.
   c) Orientation of individual buildings is a function of the type of building, type of enterprise, and desired outcome of the structure's use.

2. A plastic display of an area of land (perhaps borrowed from a geography instructor) is a very good visual tool to use when teaching this topic. Taking the class outside and showing them local topographical features around the school also provides a good introduction to this topic. Ask students to describe features of the topography that may affect farmstead planning.

   How does topography affect farmstead planning?

   a) Drainage and pollution are of particular concern when considering topography.
      1) Drainage
         (a) Drainage of water from rain, snow, ice melt, or farm operations should be away from structures, with a slope of 3 to 5 percent.
         (b) This slope will allow for drainage without promoting erosion.
         (c) Water can also damage structures if allowed to drain into them, which is why a slope away from structures is advisable.

        2) Pollution
            (a) Understanding a given area's topography will provide an understanding of the direction and routes of drainage.
            (b) Structures such as dams, holding ponds, or routing channels are sometimes effective in controlling the effects of pollution in a given area.
    b) Topography is also a significant factor in regard to accessibility for machinery, water retention, and soil components.

3. Show students pictures of the "dust bowl" of the 1930s. (Pictures may be available in history books in the school library or on the Internet). Ask them to define wind erosion. Discuss how wind affects farmstead planning.

    How does wind affect farmstead planning?

    a) A key to success in dealing with wind erosion is wind breaks, which are rows of trees strategically planted and spaced to interrupt a prevailing wind.
    b) Wind must also be considered when planning for enterprises that involve odors or airborne contaminants.
        1) Prevailing winds can be an advantage if they blow away from an area where windborne contaminants may cause problems.
        2) If a prevailing wind is carrying contaminants into an inappropriate area, the most effective solution is to locate the source of the odors or contaminants at a distance from other activities.
    c) Heating and cooling requirements are affected by wind.
        1) Prevailing winter winds from the north are of considerable concern when evaluating heat requirements.
        2) Orienting farm structures to take advantage of wind for ventilation can help in meeting cooling requirements as well as in enhancing livestock health.

4. Natural resources are often necessary for the success of a farmstead. Ask students to list some natural resources. After several have been named, ask students to list some effects farming can have on the resources listed.

    How does the potential of the natural resources base in comparison to environmental impact affect the farmstead plan?

    a) Natural resources are material sources of wealth that occur in a natural state, such as timber, water, or mineral deposits.
    b) They must be used in compliance with the codes and regulations governing their use that are designed to protect the environment and its inhabitants.
    c) This focus on regulations greatly affects farmstead planning.
        1) Any fuel, waste products, or chemicals used in amounts considered to be at a commercial level will be regulated.
        2) Of particular concern is any contaminant that can enter and be spread in the watershed, contaminating valuable natural resources.

5. Discuss different types of agricultural enterprises and how the size of the operations affects the farmstead plan. List key points on the chalkboard.

    What is the effect of type and size of business on farmstead planning?

    a) Farm acreage needs
        1) Different enterprises require acreage suitable for their needs.
        2) Careful consideration of future needs must take place during the first stages of planning if possible.
    b) Number and type of structures

        1) The number and type of structures on a farmstead also must be adapted to the specific operation's needs.
        2) When planning a farmstead, an individual must do research to find information concerning the type of structures needed for a particular operation.
            (a) Trade associations dealing with a particular type of enterprise
            (b) University Extension Services
            (c) Contract producers in the swine or poultry industries who work closely with the processors with whom they contract to develop plans for farmsteads and structures designed for efficient operation
    c) Number and type of regulations
        1) Research is required to determine what regulations might affect each aspect of the farmstead being planned.
            (a) County planning and zoning office
            (b) County Extension offices
        2) As a rule, larger operations require more and larger structures and produce more waste. They are therefore subject to more regulations.
    d) Financing options
        1) Structures are expensive to construct and maintain, so careful planning is required when determining structural needs.
        2) Obtaining professional advice concerning farm financing is recommended; in areas where agricultural enterprises are common, professional accountants experienced in financing should be available.
    e) Sources and amount of water
        1) Water needs should be anticipated and evaluated in the planning stage.
        2) The types of water sources and amounts they can deliver must be considered as well.
        3) Planning for structures should take into account convenient access to water supplies and drainage of wastes away from water sources.
        4) Laws and regulations may affect the options for water for the operation.
    f) Waste management
        1) Waste management must be planned according to the codes and regulations governing the enterprise.
        2) Waste management structures such as holding tanks or lagoons are critical for the environment and must be planned carefully.

6. Utilities and services take many forms. Discuss some of the more common ones with the class and list them on the chalkboard. Ask the students some of the ways utilities and services affect the farmstead.

How do services and utilities affect the farmstead plan?

a) Utilities of an acceptable level and dependability must be available at a cost that will allow profitable operation.
b) Services that affect the particular enterprise in question must be available and consistent enough to allow profitable operation.
    1) Electricity
    2) Passable roads
    3) Fire protection
    4) Ambulance services
    5) Telephone services
c) Utilities and services must be considered when arranging the layout of structures.
    1) Overhead electrical lines should be located away from trees if possible, since falling limbs may break lines.
    2) Underground lines tend to be more dependable.
    3) If water is supplied by a municipal source, structures must have suitable hookup access.

7. Discuss with students how a farming operation can affect neighbors or how a neighboring operation could affect the farmstead. After introducing this topic, ask students if they know of any situations where an operation affected a neighbor either positively or negatively.

How do neighbors affect farmstead planning?

a) Laws and regulations, particularly zoning laws, will dictate much of what is acceptable when planning in regard to the neighborhood surrounding the farmstead.
b) The potential for zoning changes and urban encroachment in the future should be taken into account.
c) Some concerns need to be considered, such as pollution and runoff that may affect neighbors, especially when planning structures that involve or alter watershed activity.
d) Fences that separate properties and are used by both parties are worthy of consideration when forming a farmstead plan.

8. Discuss the purposes and functions of the regulatory agencies discussed below. The main focus of the EPA and DNR--protecting the environment--should be emphasized. Have students complete AS 2.1 and AS 2.2.

What is the impact of regulatory agencies on farmstead planning?

a) Regulatory agencies designed to protect the environment, its inhabitants, and natural resources have a direct effect on most farm enterprises.
b) Compliance with regulations for such things as pollution control can be costly and involve considerable labor.
c) Regulations may limit the size an enterprise can operate at successfully.
d) Regulations also work to ensure that the environment is safe for everyone.
e) Two major regulatory agencies provide guidelines and answers to questions for farmstead planning.
    1) Environmental Protection Agency
    2) Department of Natural Resources

F. ***Other Activities***

Have students research a particular code or regulation that affects farmstead planning in their area. What is the regulation designed to protect? How does it affect farmstead planning?

G. ***Conclusion***

Developing a good farm plan is a large undertaking that requires a lot of thought and research into the particulars of the enterprise. Because of the variety and diversity of enterprises, every plan will be different. The information presented in this lesson outlines questions to be asked during the planning process so that the farmstead can operate successfully.

H. ***Answers to Activity Sheets***

I. ***Answers to Evaluation***

1. c
2. c
3. d
4. a
5. Department of Natural Resources and the Environmental Protection Agency
6. Wind breaks

7. Answers may include any two of the following: electricity, passable roads, fire protection, ambulance services, and communications services.

8. Answers may include any of the following: laws and regulations, particularly zoning laws, that dictate much of what is acceptable in regard to the neighborhood; the potential for zoning changes and urban encroachment; pollution and runoff that may affect neighbors; or fences that separate properties and are used by both parties.

Name ____________________________

Date ____________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following are of particular concern when considering topography?

    a. Wind, natural resources
    b. Wind, drainage
    c. Drainage, pollution
    d. Natural resources, water retention

2. Structures associated with related activities should be located:

    a. Close to roads.
    b. Next to sources of water.
    c. Close to each other.
    d. Next to power lines.

3. When considering environmental impact on natural resources, what is of particular concern?

    a. Wind erosion
    b. Altering topographical features
    c. Airborne contaminants
    d. Contaminants in the watershed

4. When planning a farmstead, which of the following is not affected by the size and type of business?

    a. Prevailing winds
    b. Financing option
    c. Waste management
    d. Acreage needs

Complete the following short answer questions.

5. What are two major regulatory agencies that may affect a farmstead?

    a.

    b.

6. What is one way to deal with wind erosion?

7. What are two types of services that are important to consider during farmstead planning?

    a.

    b.

8. What is one thing to consider when planning a farmstead that takes neighbors into account?

Lesson 2: Arranging a Farmstead Name ___________________________

Farmstead Planning

Objective: Understand a farmstead plan.

For each question, list two factors that would affect a farmstead plan for a beef cattle operation and a short explanation describing the effect of each of them.

1. How does the direction of the layout affect the farmstead planning?

2. How does topography affect the farmstead planning?

3. How does wind affect farmstead planning?

4. How does the potential of the natural resources base in comparison to environmental impact affect the farmstead plan?

5. What is the effect of the type and size of business on farmstead planning?

6. How do services and utilities affect farmstead planning?

7. How do neighborhoods affect farmstead planning?

8. What is the impact of regulatory agencies on farmstead planning?

Lesson 2: Arranging a Farmstead Name ____________________

Planning a Farmstead

Objective: Prepare a farmstead plan.

Even the simplest of farmstead plans can be very complex. The goal of this activity is to understand the questions to be asked and how they may be answered, particularly by locating and identifying regulatory agencies that affect decisions.

Develop a farmstead plan of your ideal farm, using the study questions as a guide. Sketch the layout of your ideal farmstead, and then briefly explain how your farmstead addresses the discussion questions in paragraph form on an attached paper. Be sure to include how you designed your farmstead in relation to topography, wind, natural resources, type and size of business, service and utilities, the home, neighbors, and how government agencies would possibly view your plan. Be creative!!!

UNIT II - HOME AND FARMSTEAD PLANNING

Lesson 3: Livestock Manure Management Systems

***Competency/Objective*:** Describe characteristics of disposal systems for managing livestock manure.

Study Questions

1. **What are the principles of a manure management system?**
2. **What regulatory agencies are involved in manure management?**
3. **Where can help be obtained for planning a manure management system?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit II.
2. Activity Sheet
    a) AS 3.1: Resources for Manure Management

UNIT II - HOME AND FARMSTEAD PLANNING

Lesson 3: Livestock Manure Management Systems

TEACHING PROCEDURES

A. *Review*

Lesson 1 of this unit discussed various aspects of farmstead planning. This lesson addresses the need for livestock manure management. Handling manure effectively is vital to prevent surface and ground water pollution.

B. *Motivation*

Discuss the importance of manure management with the class. Explain that manure accumulates very quickly in confined areas such as feed lots and poultry houses. Point out that livestock manure contains nitrogen and phosphorous that, in large amounts, can seriously damage the environment. Manure, if not properly managed, can easily contaminate water supplies through runoff or leaching through the soil into the groundwater.

C. *Assignment*

D. *Supervised Study*

E. *Discussion*

1. Discuss the principles of manure management systems with students.

What are the principles of a manure management system?

a) The main goal of manure management systems is to prevent surface and ground water pollution.
b) A manure management system generally consists of some form of manure storage and handling.
    1) For livestock operations in which the animals are kept on a well-maintained pasture, manure storage and handling is generally not an issue, because the manure is spread throughout the pasture.
    2) When animals are kept on lots or in some sort of confinement system, the manure that they produce must be handled efficiently.
        (a) To avoid pollution
        (b) To maintain sanitation
        (c) To make use of the nutrients in the manure for fertilizer
    3) Producers have a number of options for managing manure.
        (a) Depend on the conditions of the livestock operation
        (b) Common storage options
            (1) Pits underneath buildings with slotted floors
            (2) Storage tanks
            (3) Lagoons
        (c) Common methods for applying the manure
            (1) Pumping it through irrigation systems
            (2) Applying it using some type of mechanical spreader
    4) The exact type of manure disposal system needed will be dictated by many factors.
        (a) Size and type of enterprise
        (b) Location
        (c) Costs
        (d) Local zoning regulations

        - (e) Volume
        - (f) Odor considerations
        - (g) Proximity of neighbors
        - (h) Use of manure as fertilizer for crops

2. Ask students to name regulatory agencies involved in manure management. Discuss their activities.

   What regulatory agencies are involved in manure management?

   - a) Department of Natural Resources (DNR)
     - 1) Monitors natural settings
       - (a) Soil and water quality
       - (b) Effect of pollution
     - 2) Enforces regulations
     - 3) Provides information about designing livestock manure systems
   - b) Environmental Protection Agency (EPA)
     - 1) Responsible for the enforcement of federal environmental policies and laws
     - 2) Provides information on the laws and rules governing the use of manure

3. A general discussion of the complexities of manure management is needed here to bring to light the fact that one design will not meet the needs of every operation. As a rule, individual systems must be designed to address specific conditions and needs of a given enterprise. Ask students where they would obtain help if they were trying to choose a manure management system for an operation. Discuss the various sources. Have students complete AS 3.1.

   Where can help be obtained for planning a manure management system?

   - a) University Extension offices
   - b) Natural Resource Conservation Service (NRCS) offices
   - c) Associations for a particular species of livestock
     - 1) National Pork Producers Council
     - 2) National Cattlemen's Beef Association
   - d) Private agricultural engineering firms
   - e) For producers with contracts with large corporations, engineers who assist with design that are hired by the corporation

F. ***Other Activities***

Have the students do research and bring to class some recent news articles concerning livestock manure. Discuss the articles with the class.

G. ***Conclusion***

Livestock manure has the potential to be harmful to people and the environment, so proper management is critical to livestock enterprises. Manure management is an enterprise-specific process, and no one system is appropriate for every operation. Help and guidance is readily available from government agencies, livestock associations, and other sources. These resources should be utilized fully.

H. ***Answers to Activity Sheet***

I. ***Answers to Evaluation***

1. b
2. a

3. Answers may include any two of the following: the local University Extension office, the NRCS office, the National Cattlemen's Beef Association, or a private agricultural engineering firm.

4. Answers may include any three of the following: size and type of enterprise, location, costs, local zoning regulations, volume, odor considerations, proximity of neighbors, and use of manure as fertilizer for crops.

5. Department of Natural Resources and Environmental Protection Agency

6. A manure management system generally consists of some form of manure storage and handling.

UNIT II - HOME AND FARMSTEAD PLANNING Name ______________________

Lesson 3: Livestock Manure Management Systems Date ______________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is a resource for information concerning livestock manure management?

   a. American Society of Engineers
   b. University Extension services
   c. Department of Animal Health
   d. U.S. Society of Veterinary Practitioners

2. The greatest threat to the environment from manure is:

   a. Surface and ground water pollution.
   b. Air pollution.
   c. Chlorate toxicity.
   d. Insect population explosions.

Complete the following short answer questions.

3. What are two sources of information that would be helpful in the planning of a manure management system for an independent beef cattle operation consisting of feed lots supporting 500 head of cattle?

   a.

   b.

4. What are three factors that will affect the type of manure management system chosen?

   a.

   b.

   c.

5. What are two government agencies that are involved in regulating manure management?

   a.

   b.

6. What does a manure management system generally consist of?

Lesson 3: Livestock Manure Management Systems Name ____________________________

Resources for Manure Management

Objective: Develop research skills and locate sources of information concerning manure management.

Find addresses, telephone numbers, and web sites (if possible) for one of the following sources of information about manure management. These groups help define the regulations affecting manure management and the acceptable types of management systems.

- Department of Natural Resources ***or*** Environmental Protection Agency (national and state level)
- Natural Resource Conservation Service (NRCS)
- University Extension (state and local level)
- Professional associations, such as the Cattlemen's Association (national and state level)

Conduct research into one of these agencies or associations (obtaining materials from them if possible). Prepare a report discussing their duties and the type of information available from the source of information you have chosen.

UNIT III - BUILDING CONSTRUCTION

Lesson 1: Construction Safety

***Competency/Objective*:** Describe safety practices associated with building construction.

Study Questions

1. **What are safety factors to consider when working with heights?**
2. **What are safety factors to consider when working with construction equipment and tools?**
3. **What are safety factors to consider when working with structural elements?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit III.
2. Activity Sheet
    a) AS 1.1: Safety on the Construction Site

UNIT III - BUILDING CONSTRUCTION

Lesson 1: Construction Safety

TEACHING PROCEDURES

A. *Introduction*

Accidents occur in the construction and agriculture industries all the time. In combining the activities of the two industries, a very dangerous array of work conditions exists. Taking precautions is necessary when participating in any construction project around the farm. While every possible hazard involved in agricultural construction cannot be addressed in a single lesson, this lesson outlines some specific recommendations for safety in constructing agricultural structures.

B. *Motivation*

Discuss the Bureau of Labor statistics for 1997 given below. They indicate just how dangerous both the construction and agriculture industries can be. (Only the industry division for transportation and public utilities and the division for mining have a similarly high number of fatalities relative to the numbers for total employment.)

Percentage of total workforce involved in each industry division

Services	28%
Retail trade	17%
Manufacturing	16%
Government	15%
Construction	6%
Agriculture, forestry, and fishing	3%

Percentage of total fatalities for all workplace incidents

Services	12%
Retail trade	11%
Manufacturing	12%
Government	10%
Construction	18%
Agriculture, forestry, and fishing	13%

C. *Assignment*

D. *Supervised Study*

E. *Discussion*

1. Ask students if they have ever worked on a roof or on top of a tall ladder. Did they take any measures to keep injuries and accidents from occurring? Discuss safety measures that could be taken to prevent injuries.

   What are safety factors to consider when working with heights?

   a) Equipment must be well maintained and in good working order.
   b) The base of a ladder or the legs of a scaffold must be evenly set on a solid, non-slippery surface.

c) Any applicable safety equipment, such as safety belts and boots with non-skid soles, should be used.
d) Use extra caution when carrying roofing materials and carry small, manageable loads.
e) Move slowly and carefully because roofs can be slick.
f) Do not attempt to work at heights if experiencing any dizziness or disorientation.

2. Have students look at an assortment of simple tools (hammers, screwdrivers, saws, drills, etc.) that might be used in construction. Ask them to imagine the kinds of injuries that could occur when using these tools. Do they know anyone who has been seriously injured when building something? Discuss safety factors to consider to prevent similar accidents.

What are safety factors to consider when working with construction equipment and tools?

a) Keep tools well maintained and in proper working order.
b) Use tools and equipment for their intended purpose.
c) Follow the manufacturer's instructions for the use of equipment and tools and take heed of any safety recommendations.
d) Fatigue can lead to carelessness; take breaks as needed.

3. Ask students to list the different types of materials that may be used when constructing a building. What sorts of injuries might occur when working with these materials? Discuss the different factors that may prevent these injuries. Have students complete AS 1.1.

What are safety factors to consider when working with structural elements?

a) Care should be taken when loading and unloading; avoid standing where materials (or the equipment handling them) could be a hazard in the event of a mishap.
b) Care and good technique are necessary when lifting construction materials.
    1) They should be moved in some other way if possible, such as pushing, rolling, or sliding.
    2) If construction materials must be lifted, the best way to do so is to bend at the knees, keeping the back straight, and lift the object by straightening the legs; reverse the process when setting materials down.
    3) To turn, the feet should be moved to a new position; twisting at the waist should be avoided to prevent back injuries.
c) Some materials, such as concrete, may be caustic and should be handled wearing protective clothing and boots.
d) Electrical hook-ups should only be assembled by someone who is very knowledgeable and qualified to establish such service; sufficient grounding and circuit breaking devices must be in place.
e) Materials and waste materials should be kept organized and out of the way while working to prevent tripping.

F. *Other Activities*

Have the students (possibly working in small groups) search news articles for examples of construction accidents and bring them to class. Discuss how these accidents might have been avoided.

G. *Conclusion*

The safety tips about working with heights, tools and equipment, and structural elements that are given in this lesson address only a few of the areas of concern. Every worker needs to pay attention and use good judgement. Staying alert can help avoid injury when working on agricultural structures.

H. *Answers to Activity Sheet*

Suggested answers are given below.

1. Tools should be well-maintained; manufacturer's instructions and safety recommendations should be followed; tools should be used for their intended purpose; use protective clothing such as gloves, long pants, ear protection, and safety glasses.

2. Set the base of the ladder securely; carry small, manageable loads; use good lifting technique; move slowly on the roof; wear boots with non-skid soles when working on the roof.

3. Take care when unloading materials and avoid standing in their path in case of an accident; lift materials safely; wear protective clothing such as gloves and work boots.

4. Keep waste materials out of the way; lift materials safely; wear protective clothing such as gloves and a hard hat.

I. ***Answers to Evaluation***

1. d
2. c
3. b

4. Answers may include any two of the following.
   - Keep tools well maintained and in proper working order.
   - Use tools and equipment for their intended purpose.
   - Follow the manufacturer's instructions for the use of equipment and tools and take heed of any safety recommendations.
   - Fatigue can lead to carelessness; take breaks as needed.

5. If you are experiencing dizziness or disorientation
6. To prevent tripping

UNIT III - BUILDING CONSTRUCTION

Lesson 1: Construction Safety

Name ______________________________

Date ______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. When lifting objects:
    a. Bend at the waist.
    b. Lift using only the arms.
    c. Lift with the back bent.
    d. Bend at the knees.

2. Which of the following is a safety factor to consider when working with heights?
    a. Carry large loads of materials to prevent making too many trips.
    b. Move quickly to avoid spending too much time moving around.
    c. Set the base of a ladder evenly on a solid, non-slippery surface.
    d. Wear tennis shoes to keep from slipping on the roof.

3. To turn when lifting materials:
    a. Twist at the waist.
    b. Reposition the feet.
    c. Turn at the knees.
    d. Reposition the arms.

Complete the following short answer questions.

4. What are two safety factors to consider when working with tools?
    a.
    b.

5. When should you not attempt to work on a height?

6. Why should materials and waste materials be kept organized and out of the way while working?

Lesson 1: Construction Safety Name ____________________

Safety on the Construction Site

Objective: Identify safety measures that should be taken in various construction situations.

Some common construction situations are described below. List three or four safety rules that would apply to each situation, including any protective clothing that would need to be worn.

1. You are beginning to construct wooden walls, using hammers, air nailers, saws, and other woodworking equipment.

2. You are roofing a new two-story house. Additional materials are on the ground and need to be moved onto the roof before you can continue roofing.

3. At the building site you are working on, they have just finished taking the forms off the concrete for the basement. You are ready to begin the flooring. The materials you need have just arrived on a truck from the lumber yard.

4. You are cleaning up the work site while other workers construct the roof. They throw the waste materials from the top of the building to the ground.

Lesson 2: Building Designs

***Competency/Objective*:** Identify types and designs of buildings and their methods of construction.

Study Questions

1. **What are different designs and uses of agricultural structures?**
2. **What are advantages and disadvantages of different types of structures?**
3. **What factors should be considered when designing and constructing agricultural structures?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit III.
2. Activity Sheet
    a) AS 2.1: Identifying Building Designs

TEACHING PROCEDURES

A. ***Review***

Lesson 1 discussed safety factors to consider when constructing agricultural structures. The designs of these structures are as varied as the enterprises for which they may be used. A few types of designs and building materials are more commonly used than others. This lesson describes some of the different designs used in agriculture.

B. ***Motivation***

Discuss the diversity of agricultural structures in your area. They will most likely include pole barns, storage buildings, animal housing facilities, grain processing/storage structures, machinery sheds, workshops, etc.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Ask students to describe the shapes and roof types of agricultural structures with which they are familiar and list them on the board for discussion. Discuss the different types of materials used in construction.

What are different designs and uses of agricultural structures?

a) Basic shapes of structures
    1) Square
    2) Rectangle
    3) Circle
    4) Oval
    5) Some combination of these shapes
b) Seven roof styles
    1) Gable
    2) Hip
    3) Mansard
    4) Gambrel
    5) Shed
    6) Quonset
    7) Gothic/arched
c) Methods of construction
    1) Wood frame - Weight-bearing upright wooden members are used for the walls of the building.
    2) Pole - Large wooden timbers are placed in the ground and serve as the weight-bearing skeleton of the building.
    3) Metal - Metal is used as a primary component of the building, which is constructed by welding and bolting the materials together.
    4) Masonry - Concrete or masonry blocks are the primary building material; buildings are constructed by pouring concrete in forms or laying blocks.

2. Ask students to list some advantages and disadvantages associated with each type of structure. Emphasize that each situation may be different, so advantages and disadvantages must be carefully evaluated in regard to the use of a specific structure. Have students complete AS 2.1.

What are advantages and disadvantages of different types of structures?

a) Wood frame
  1) Advantages
    (a) More economical than the other types of structures
    (b) Easy to partition or expand
  2) Disadvantages
    (a) Higher maintenance requirements
    (b) May not be durable under conditions of abusive use
    (c) Inherent fire hazard
b) Pole
  1) Advantages
    (a) Rapid and economical construction
    (b) Long life span
    (c) Partitioning or expansion usually easily accomplished
  2) Disadvantages
    (a) Inferior weather protection
    (b) Cannot be heated or cooled without modifications being made to the structure
c) Metal
  1) Advantages
    (a) Serviceable for a long time
    (b) Fire resistant
  2) Disadvantages
    (a) Expensive
    (b) Special equipment and considerable skill required for construction
    (c) Can be short-lived around manure
d) Masonry
  1) Advantages
    (a) Easily cleaned and disinfected
    (b) Fire resistant
    (c) Very long life span
    (d) Minimal maintenance requirements
  2) Disadvantages
    (a) Expensive
    (b) Extensive excavation required, depending on the topography
    (c) Requires a lot of labor to tear down masonry for expansion

3. Discuss the various factors that should be considered when designing and constructing a structure for use in an agricultural enterprise. Hand out AS 2.1.

What factors should be considered when designing and constructing agricultural structures?

a) Identify the intended uses of the structure.
b) Consider whether the cost of construction is reasonable enough to allow successful operation or use.
c) Determine whether the proposed structure is appropriate for local environmental conditions.
d) Consult codes and regulations for construction.
e) Consider whether materials are used efficiently.

F. ***Other Activities***

Have the students work in groups and build small models (birdhouse size) of some of the building styles mentioned in this lesson, such as a shed with a hip or gable roof. Small wood stock or even cardboard and glue would be suitable for materials.

G. *Conclusion*

Selecting an appropriate design is very important when constructing an agricultural structure. Material selection, construction methods, costs, and codes all must be considered to produce a building with the desired advantages. Resources are readily available to assist in planning and producing a building that will serve its intended purpose.

H. *Answers to Activity Sheet*

I. *Answers to Evaluation*

1. d
2. b
3. c

4. Poured concrete in forms or concrete blocks

5. Answers may include any three of the following.

    - Identify the intended uses of the structure.
    - Consider whether the cost of construction is reasonable enough to allow successful operation or use.
    - Determine whether the proposed structure is appropriate for local environmental conditions.
    - Consult codes and regulations for construction.
    - Consider whether materials are used efficiently.

6. Answers may include any two of the following: rectangle, square, circle, or oval.

7. In pole construction, large timbers are placed in the ground and serve as the weight-bearing skeleton of the building.

UNIT III - BUILDING CONSTRUCTION

Name ____________________________

Lesson 2: Building Designs

Date ____________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is a disadvantage of wood frame construction?
   - a. Inferior weather protection
   - b. Difficult to partition or expand if necessary
   - c. Extensive excavation required for building
   - d. Requires more maintenance

2. One of the advantages of metal designs is that structures are:
   - a. Very easy to build.
   - b. More fire resistant than others.
   - c. Easily cleaned and disinfected.
   - d. Very inexpensive to build.

3. An advantage of masonry construction is that:
   - a. Structures can be rapidly constructed.
   - b. Partitioning is usually easily accomplished.
   - c. They have a very long life span.
   - d. They do not have to be heated.

Complete the following short answer questions.

4. What are the materials used for masonry construction?

5. What are three factors that should be considered when choosing a design for an agricultural structure?
   - a.
   - b.
   - c.

6. What are two basic shapes used in building designs?
   - a.
   - b.

7. What is pole construction?

Lesson 2: Building Designs

Name ___________________________

Identifying Building Designs

Objective: Identify different types of building designs.

Answer the questions below.

1. What types of enterprises are common in your area?

2. Choose one of the enterprises you listed above. What structures are used for that type of enterprise?

On a separate sheet of paper, paste pictures of each of the different structures listed above. Include at least ten pictures. They may be photographs you have taken yourself or pictures clipped from a magazine or some other source. Next to the picture, describe the design of the structure in terms of the shape, roof style, and type of materials used.

UNIT III - BUILDING CONSTRUCTION

Lesson 3: Building Materials

***Competency/Objective*:** Identify and select building materials.

Study Questions

1. **What are the different types of building materials?**
2. **What are the types and grades of dimension lumber?**
3. **What are the types and grades of sheathing materials?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999.
2. Transparency Master
    a) TM 3.1: Typical APA Plywood Grade-Trademark
3. Activity Sheet
    a) AS 3.1: Construction Materials

Lesson 3: Building Materials

TEACHING PROCEDURES

A. ***Review***

Lesson 2 discussed different types of building designs. Lesson 4 describes the types of building materials that may be used to build these designs, with an emphasis on wood products. This lesson discusses the types of materials available and how to determine the quality of the material by its grade.

B. ***Motivation***

Pass around a few samples of scrap dimensional lumber and small pieces of sheathing. Samples can be acquired from local lumber yards or possibly construction sites. Try to get a variety of common sizes in short lengths of a foot or so. Also, obtain a few small examples of plywood in different thickness and of nonveneered samples, such as particle board and oriented strand board. As these materials are being passed around, tell the class the focus of this lesson will be on identifying and understanding the grades of these types of materials.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Discuss the types of building materials available.

   What are the different types of building materials?

   a) Wood products, including boards and plywood
   b) Metals, such as steel and aluminum
   c) Concrete products
   d) Clay bricks and tiles
   e) Vinyl, plastics, glass, and fiberglass

2. Discuss the different types and grades of dimension lumber. Have the samples used for the motivation available to provide examples during the discussion.

   What are the types and grades of dimension lumber?

   a) Dimension lumber - Wooden building material sawn in lengths, usually starting at eight feet and increasing in increments of two feet, and uniform in thickness and width
   b) Types of dimension lumber
      1) Softwood is lumber from evergreen trees.
      2) Hardwood is from deciduous trees.
      3) Treated lumber is chemically treated for preservation.
      4) Green lumber is lumber with a high moisture content.
      5) Kiln-dried lumber is dried in a kiln, a sort of oven in which the lumber is heated to reduce moisture to a desired point.
   c) Grades of lumber
      1) The American Lumber Standards Committee sets certain standards for grading lumber that are generally applied, and often expanded or detailed, by regional associations such as the Western Wood Products Association or Southern Forest Products Association.

2) Lumber is generally graded 1, 2, or 3 (1 being the highest number grade), possibly with an additional premium or select grade.
3) Grading is accomplished by evaluating the number and severity of defects.
    (a) Knots
    (b) Splits and checks
    (c) Shakes
    (d) Pitch pockets
    (e) Honeycombing
    (f) Wane
    (g) Blue stain
    (h) Decay
    (i) Holes
    (j) Warp
4) The designation "economy" generally is equivalent to grade three.
5) Some areas may have further designations involving letters or terms such as (S) or Select, (B) or Better, (C) or Common, Choice, or Supreme; these letters may or may not correspond to a number system.
6) Treated lumber usually does not have a number or letter grade; it is simply referred to as "treated."

3. Discuss common types and grades of sheathing materials available for construction uses. TM 3.1 will be of assistance in discussing the information stamped on sheathing material. Have students complete AS 3.1.

What are the types and grades of sheathing material?

a) Sheathing materials - generally wood or wood product panels that most commonly are four feet by eight feet in size, with a thickness of ¼ to 1 7/16 inches
b) Types of sheathing materials
    1) Plywood - made of thin sheets of wood laminated to a desired thickness.
    2) Composite plywood - has a veneer cover laminated to some form of wood core.
    3) Nonveneered panels, consisting of oriented strand board (OSB), particle board, and wafer board - made from wood flakes, chips, or fibers that are combined with suitable resins and glues and shaped into panels
c) Grades of sheathing materials
    1) Softwood plywood grades - assigned by associations such as the APA to sheathing materials manufactured to meet their specifications.
        (a) Generally, a rating of 1 indicates that the plywood is for exterior use, while a rating of 2 is for interior use.
        (b) Plywood with a rating of "Exposure 1" can withstand moisture but should be used indoors, while "Exposure 2" indicates plywood that should only be used indoors.
        (c) Letter system - used to rate the quality of the veneer used on the face and back
        (d) Plywood grade stamp from the APA
            (1) Span rating - Two numbers separated by a slash; the first number is the maximum span in inches that should be used for roof decking, while the second number is the recommended span for floor decking
            (2) Panel grade
            (3) Exposure durability
            (4) Thickness
    2) Hardwood Plywood Institute
        (a) Rating of 1 or 2 - good face and back with careful grain matching
        (b) Rating of 3 - structurally sound but has obvious defects and patching
    3) Softwood or hardwood plywood - may also be designated G1S, meaning "good one side," or G2S for "good two sides."

F. *Other Activities*

1. Have the students add to your collection of sample materials.
2. Ask a knowledgeable representative from a local lumber retailer to come and speak to the class about the products and grades of lumber that the business carries.

G. *Conclusion*

The selection of building materials should be made with a good understanding of what is available along with the advantages of different types of materials. Knowing the types and grades of materials will help control costs while allowing for the construction of a structure that will fulfill its intended purpose.

H. *Answers to Activity Sheet*

I. *Answers to Evaluation*

1. b
2. c
3. c
4. b
5. a
6. Answers may include any two of the following: wood products, metals, concrete products, clay bricks and tiles, vinyl, plastics, glass, and fiberglass.
7. Softwood is lumber from evergreen trees, while hardwood is from deciduous trees.
8. Answers may include any three of the following: knots, splits and checks, shakes, pitch pockets, honeycombing, wane, blue stain, decay, holes, and warp.
9. A span rating consists of two numbers separated by a slash; the first number is the maximum span in inches that should be used for roof decking, while the other is the recommended span for floor decking.

UNIT III - BUILDING CONSTRUCTION

Lesson 3: Building Materials

Name ____________________________

Date ____________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Kilns are for:

   a. Measuring lumber.
   b. Drying lumber.
   c. Surfacing lumber.
   d. Measuring moisture in lumber.

2. What is the regulatory agency that helps set lumber grading guidelines?

   a. American Lumber Agency.
   b. Wood Products Agency.
   c. Department of American Lumber Standards.
   d. Department of Natural Resources.

3. What is a veneer cover laminated to some form of wood core called?

   a. Plywood
   b. OSB
   c. Composite plywood
   d. Dimensional lumber

4. Lumber especially designed for outside use is:

   a. OSB.
   b. Treated lumber.
   c. Dimensional lumber.
   d. Kiln-dried lumber.

5. A material made from wood flakes, chips, or fibers that are combined with suitable resins and glues and shaped into panels is called:

   a. OSB.
   b. Composite plywood.
   c. Dimensional lumber.
   d. Kiln-dried lumber.

Complete the following short answer questions.

6. What are two common building materials?

   a.

   b.

7. What is the difference between hardwood and softwood?

8. What are three types of defects in a piece of lumber?

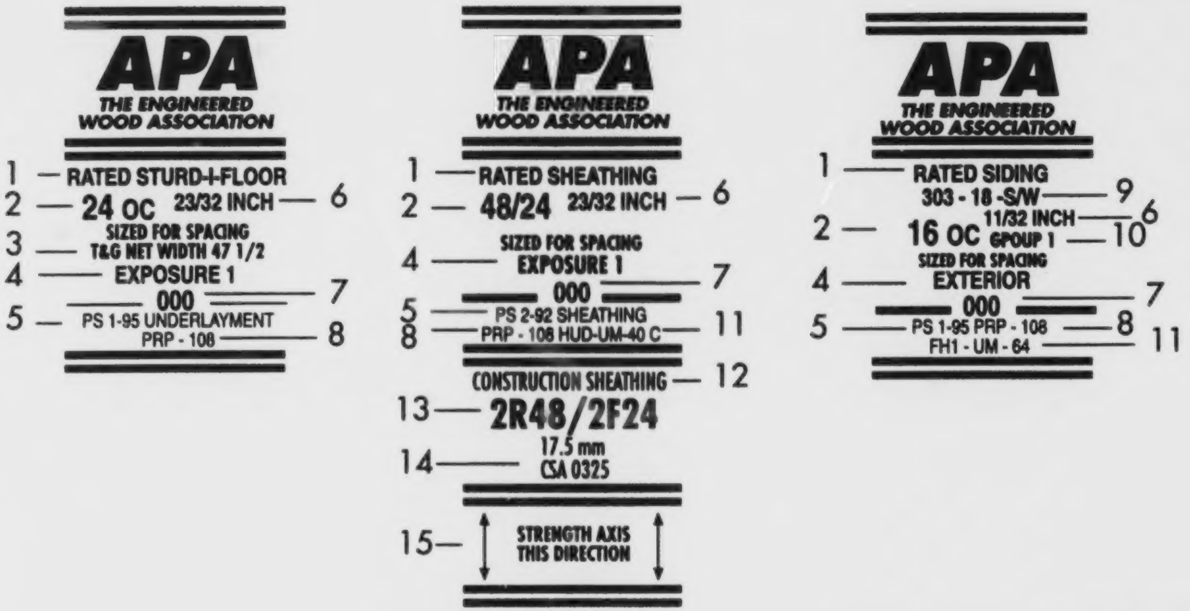
   a.

   b.

   c.

9. What does the span rating on a sheet of plywood indicate?

Typical APA Plywood Grade-Trademark


APA
THE ENGINEERED WOOD ASSOCIATION
1 — RATED STURD-I-FLOOR
2 — 24 OC 23/32 INCH — 6
SIZED FOR SPACING
3 — T&G NET WIDTH 47 1/2
4 — EXPOSURE 1
000 — 7
5 — PS 1-95 UNDERLAYMENT
PRP - 108 — 8
APA
THE ENGINEERED WOOD ASSOCIATION
1 — RATED SHEATHING
2 — 48/24 23/32 INCH — 6
SIZED FOR SPACING
4 — EXPOSURE 1
000 — 7
5 — PS 2-92 SHEATHING
8 — PRP - 108 HUD-UM-40 C — 11
CONSTRUCTION SHEATHING — 12
13 — 2R48/2F24
17.5 mm
14 — CSA 0325
15 — STRENGTH AXIS THIS DIRECTION
APA
THE ENGINEERED WOOD ASSOCIATION
1 — RATED SIDING
303 - 18 -S/W — 9
11/32 INCH — 6
2 — 16 OC GROUP 1 — 10
SIZED FOR SPACING
4 — EXTERIOR
000 — 7
5 — PS 1-95 PRP - 108 — 8
FH1 - UM - 64 — 11

1 Panel grade
2 Span Rating
3 Tongue-and-groove
4 Exposure durability classification
5 Product Standard
6 Thickness
7 Mill number
8 APA's performance rated panel standard
9 Siding face grade
10 Species group number
11 HUD/FHA recognition
12 Panel grade, Canadian standard
13 Panel mark - Rating and end-use designation, Canadian standard
14 Canadian performance rated panel standard
15 Panel face orientation indicator

Lesson 3: Building Materials Name ____________________________

Construction Materials

Objective: Compare and contrast different types of building materials.

Select one of the building materials listed below and research it to answer the following questions.

Wood products - dimension lumber
Metals - steel and aluminum
Concrete products
Clay bricks and tiles
Vinyl
Plastic
Fiberglass

1. What is this material commonly used for in building construction?

2. How is this material made or processed?

3. What safety factors should be remembered when working with this material?

4. How is this material sold, and how is it priced?

5. What are the advantages and disadvantages to using this material?

6. What finishes (paints, stains, etc.) can be used with this material?

7. What tools are needed to work with this material?

8. What fasteners can be used with this material?

Lesson 4: Fasteners and Fastening Systems

Competency/Objective: Identify the uses of different fasteners and fastening systems.

Study Questions

1. **What are the groups of fasteners and the uses of each group?**
2. **What are the factors to consider when selecting nails?**
3. **What are the types of screws and their uses in agricultural structures?**
4. **What are adhesives and their uses?**
5. **What are the types of construction anchors and their uses?**
6. **What are the types of framing anchors and their uses?**

References

1. *Agricultural Structures (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit III.
2. Transparency Masters
    a) TM 4.1: Nails
    b) TM 4.2: Nail Sizes
    c) TM 4.3: Screws
    d) TM 4.4: Sample Framing Anchors
3. Activity Sheet
    a) AS 4.1: Identifying Fasteners

TEACHING PROCEDURES

A. *Review*

The previous lesson, Lesson 3, described some of the materials used in construction. The following lesson explores the different fasteners and fastening systems as well as some of their uses. Nails, screws, adhesives, and construction anchors are all types of fasteners.

B. *Motivation*

Show the class examples of different fasteners representing each of the groups discussed in this lesson.

C. *Assignment*

D. *Supervised Study*

E. *Discussion*

1. Ask students to list different kinds of fasteners. Discuss their uses.

   What are the groups of fasteners and the uses of each group?

   a) Nails - attach pieces of wood together
   b) Screws - attach pieces of wood as well as metals
   c) Adhesives - can bond many types of materials
   d) Construction anchors - devices used to attach walls to foundations
   e) Framing anchors - attach framing members together

2. Ask students to list some different types of nails. Use TM 4.1 to illustrate the different types. Discuss how different sizes of nails are designated. Discuss the factors to consider when choosing nails for use in construction. TM 4.2 shows different nail sizes.

   What are the factors to consider when selecting proper nails?

   a) Use
      1) Common nail - general purpose nails used anywhere a special purpose nail is not needed
      2) Box nail - have a thinner head and shank and are less likely to split wood and easier to cover with paint; often used in finish cabinet work
      3) Finish nail - useful for finishing because of their very small heads, which make them less noticeable; have less holding ability because of the small head
      4) Duplex-head nail - used when nails will have to be removed because the head extending above the surface makes their removal easier; commonly used for concrete forms
      5) Roofing nail - used for nailing shingles in place; have very wide, flat heads
      6) Ring-shank nail - used for applications where the nail will never be removed and the material needs to be held tightly; often used for stair treads
      7) Screw-shank nail - twisted shaft causes the nail to turn as it is driven in, making it difficult to remove; used where good holding ability is needed, such as on decks
      8) Staple - used mostly for wire, plastics, or vinyl
   b) Length

        1) Designated by the term "penny" and the letter "d"
        2) Should be long enough to pass entirely through one board and at least half the thickness of the board to which it will be attached
    c) Exposure to weathering - Should choose nails made of materials such as zinc or aluminum that will resist corrosion or staining

3. Screws have better holding ability than nails. They are also used in combination with glues for even greater bonds. Discuss the different types of screws. Use TM 4.3 to illustrate as needed.

What are the types of screws and their uses in agricultural structures?

a) Head styles
    1) Round head
    2) Oval head
    3) Flat head
    4) Pan head
b) Slot types
    1) Straight-slot
    2) Phillips
    3) Special slot styles (square, Allen, or star)
c) Wood screw - used to attach wood
d) Self-tapping metal screw - used with sheet metal or building siding
e) Drywall screw - used to secure drywall to walls and ceilings

4. Adhesives are used today in all phases of construction, and they are expected to play an even greater role in the future. Discuss the different adhesives and their uses. Emphasize that all manufacturer's recommendations should be followed carefully, because adhesives can be dangerous.

What are adhesives and their uses?

a) Wood glue - for joining woods
    1) Polyvinyl (white wood glue) - for interior or furniture woodwork
    2) Urea formaldehyde (plastic resin glue) - for repairing wood splits or reinforcing joints in a defective truss
    3) Resorcinol resin - for wood where water exposure is likely
b) Epoxy - for extremely strong bonds; commonly used on fiberglass and plastics
c) Mastic - for materials with large surface areas, such as floor coverings; includes contact cements, which are used to attach laminates to counter tops or for vinyl floor coverings

5. Anchors include a wide range of devices, bolts, and cable systems. Discuss some of the different types of construction anchors that are used.

What are the types of construction anchors and their uses?

a) Generally used to attach walls to foundations; help protect the structure against damage from high winds by adding more strength and stability
b) Anchor bolt - large bolts set into the foundation to serve as anchors by securing the bottom of the wall to the concrete
c) Other types of anchor systems
    1) Metal straps set in concrete and then attached to the wooden member in the wall
    2) Anchors screwed into the ground with metal cables attaching them to the structure

6. Another type of anchor is a group of specially built brackets designed to attach framing pieces together. Show students examples of framing anchors using TM 4.4. Hand out AS 4.1, and assign students different groups of fasteners to research. If possible, discuss their research in class.

What are the types of framing anchors and their uses?

a) Differ from construction anchors in that they attach framing pieces together
   1) Setting joists in place
   2) Attaching the roof to the walls
   3) Attaching walls to each other
   4) Joining the parts of a truss

b) Have specific shapes for a particular purpose

F. *Other Activities*

Have students compare sample fasteners to determine where each fastener would work best and where it would not be a good choice. If possible, have students collect different types of fasteners and add them to the school's collection.

G. *Conclusion*

Five main groups of fasteners--nails, screws, adhesives, construction anchors, and framing anchors--are discussed in this lesson. Nails are the most commonly used type of fastener, while screws generally are stronger fasteners. Adhesives are now being used more frequently to join a variety of building materials. Anchors increase the strength and stability of the structure. For heavy construction, obtaining professional recommendations about the best types of fasteners to use is valuable.

H. *Answers to Activity Sheet*

I. *Answers to Evaluation*

1. a
2. c
3. d
4. c
5. d
6. Self-tapping metal screws
7. To attach walls to foundations and help protect the structure against damage from high winds by adding more strength and stability
8. Use, length, and exposure to weathering

9. Answers may include any one of the following: attaching the roof to the walls, attaching walls to each other, and joining the parts of a truss together.

Name ____________________________

Lesson 4: Fasteners and Fastening Systems

Date ____________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. A duplex-head nail is used for:

   a. Easy removal.
   b. Permanent installation.
   c. Attaching wire.
   d. Finishing.

2. White wood glue is a:

   a. Contact cement.
   b. Urea formaldehyde.
   c. Polyvinyl.
   d. Resorcinol resin.

3. The length of a nail is described by a number and the term:

   a. Weight.
   b. Inches.
   c. Dimes.
   d. Penny.

4. Which of the following nails has a twisted shaft that causes it to turn as it is driven?

   a. Ring-shank nail
   b. Finish nail
   c. Screw-shank nail
   d. Twister nail

5. Which of these adhesives is used for attaching vinyl floor coverings?

   a. Epoxy
   b. Urea formaldehyde
   c. Resorcinol resin
   d. Contact cement

Complete the following short answer questions.

6. What type of screw is used to attach sheet metal or metal siding?

7. What is the purpose of construction anchors?

8. What are three factors that affect the selection of nails?

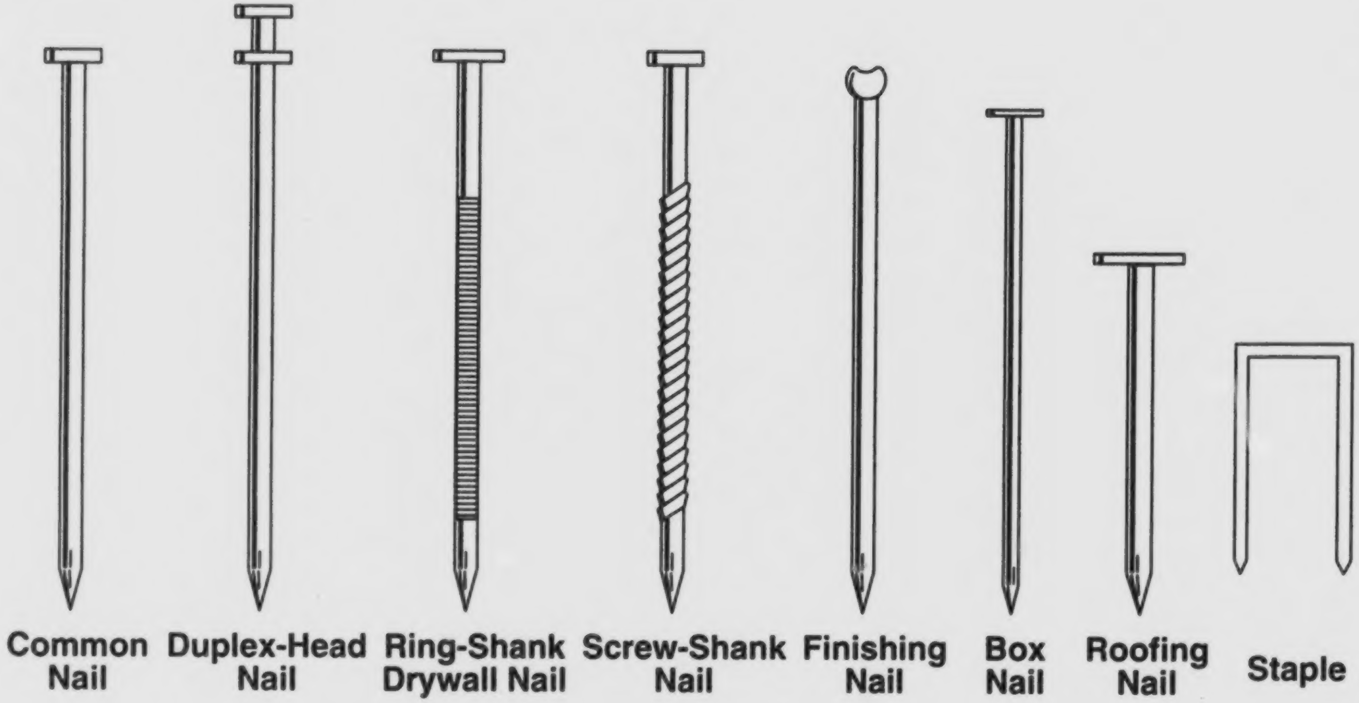
   a.

   b.

   c.

9. What is one use of framing anchors?

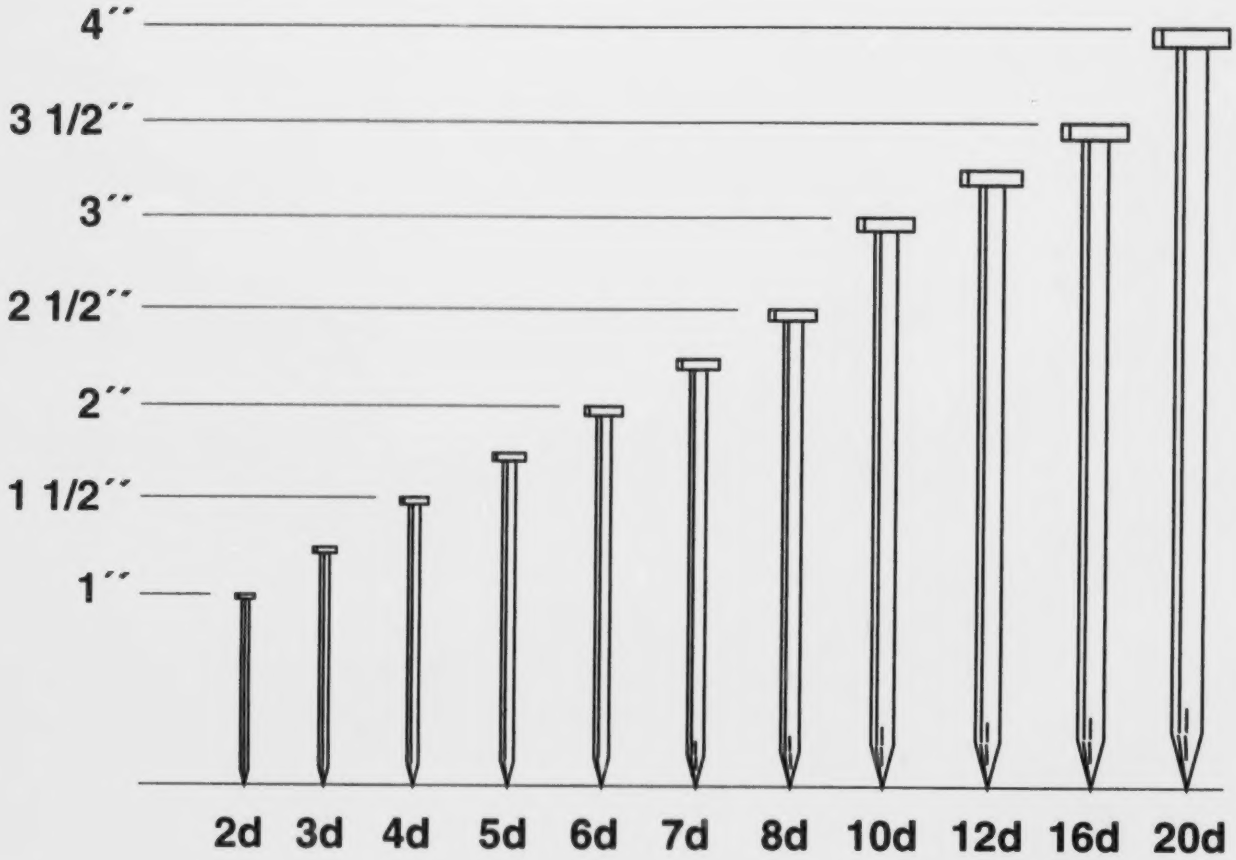
Nails


Common Nail
Duplex-Head Nail
Ring-Shank Drywall Nail
Screw-Shank Nail
Finishing Nail
Box Nail
Roofing Nail
Staple

Agricultural Structures, III-41

TM 4.1

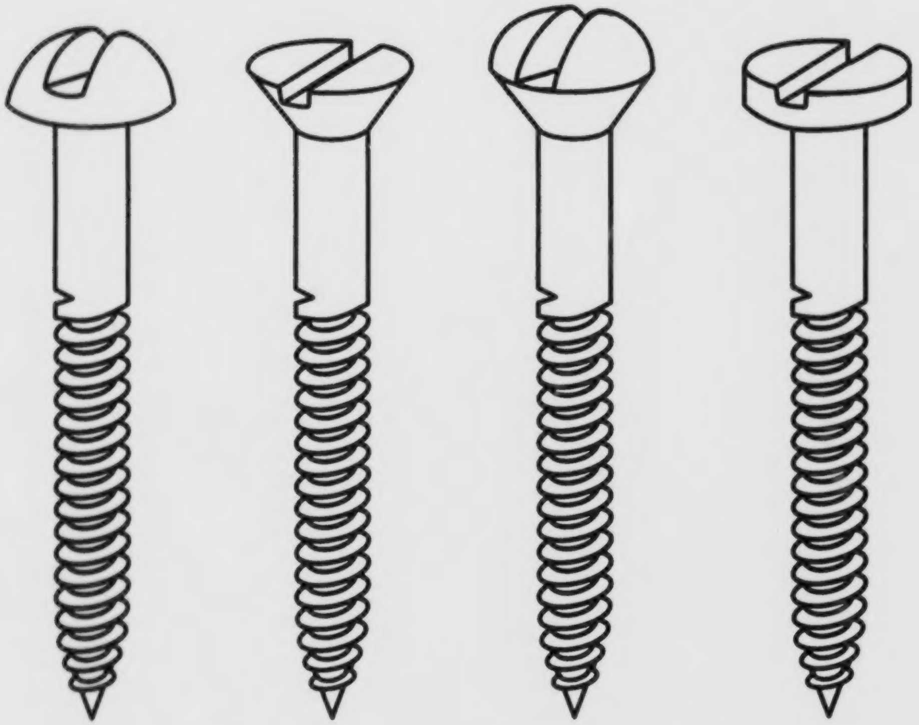
Nail Sizes



Agricultural Structures, III-43

TM 4.2

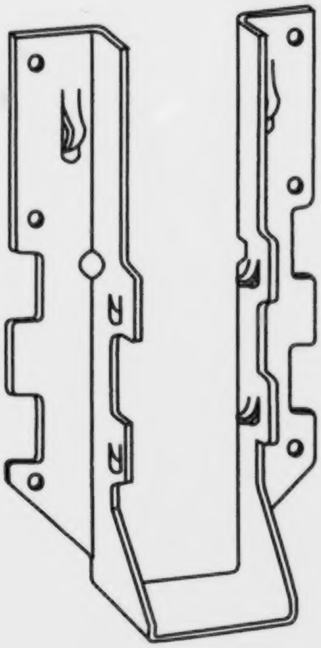
Screw Heads

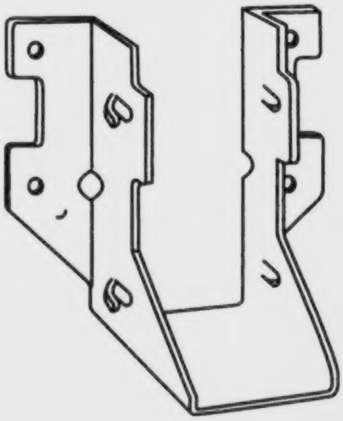

Round Head
Flat Head
Oval Head
Pan Head

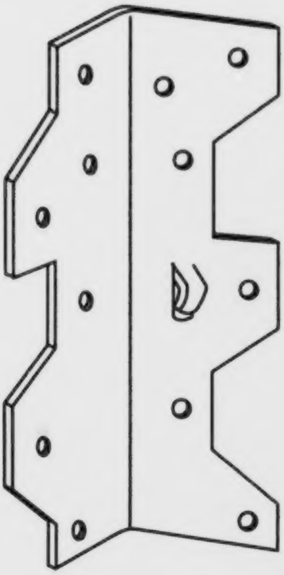
Agricultural Structures. III-45

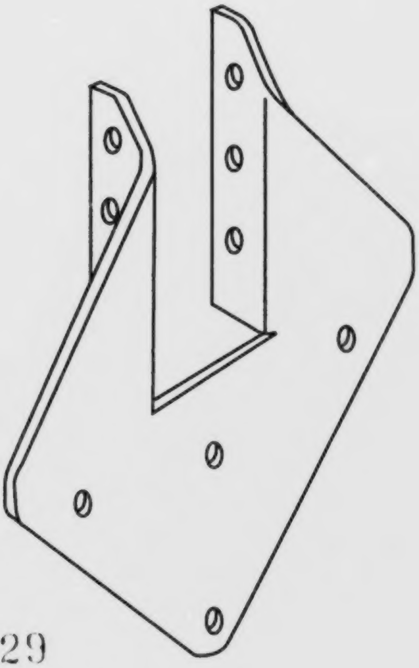
TM 4.3

Sample Framing Anchors









UNIT III - BUILDING CONSTRUCTION AS 4.1

Lesson 4: Fasteners and Fastening Systems

Name ______________________

Identifying Fasteners

Objective: Identify the uses of different fasteners and fastening systems.

Research the group of fasteners assigned by your instructor then answer the questions below. Be prepared to discuss the information with the class.

1. What are five products available in the category selected?

2. How and when can each of them be used?

3. What are the advantages and disadvantages of each?

Lesson 5: Floors and Subfloors

Competency/Objective: Describe how to construct a floor and subfloor.

Study Questions

1. **What are the members used in floor framing?**
2. **How are the joists set in place?**
3. **How is the subflooring installed?**
4. **How does load determine the type of flooring and subflooring used?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit III.
2. Transparency Masters
   - a) TM 5.1: Parts of a Floor
   - b) TM 5.2: Bridging
3. Activity Sheet
   - a) AS 5.1: Diagramming Flooring
4. Job Sheet
   - a) JS 5.1: Joist Layout

UNIT III - BUILDING CONSTRUCTION

Lesson 5: Floors and Subfloors

TEACHING PROCEDURES

A. ***Review***

Lesson 4 described the various types of fasteners and fastening systems used in construction. When building a structure, one of the first uses of fasteners is constructing a floor. This lesson concerns itself with wood or wood-metal combinations for the floor framework and subflooring. The basics of floor construction, including the members used and their assembly, will be explored.

B. ***Motivation***

Before the class period, construct a small model of a floor to display its basic components, including the sill, header joists, joists, bridging, and subflooring. The model can be made using balsa wood, small strips of pine, or Popsicle sticks. It should be small enough for the students to handle and pass around.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Ask students if they can think of some terms associated with constructing floors. Discuss the following terms. Use TM 5.1 to show different floor members. TM 5.2 illustrates bridging.

   What are the members used in floor framing?

   a) Crawl space - space between the ground and the first floor in structures without a basement
   b) Sill plate
      1) Piece of material, usually made of wood or metal, that is attached to the foundation
      2) Usually a 2-inch thick board that is 4, 6, or 8 inches wide
      3) Place where the building frame attaches to the foundation
      4) Supports the floor joists
   c) Girder or beam
      1) Large piece of dimensional wood, a combination of dimensional wood and plywood, metal, or some fabricated combination of metal and wood
      2) Supports the weight of the structure at certain points along its length
      3) Supported by posts
   d) Post - wood, metal, or concrete support for girders
   e) Header joist
      1) Attaches to the sill to form a box sill
      2) Attaches to the ends of the joists
   f) Joist
      1) Wood or metal member that rests on the sill and supports the first layer of flooring and the weight of the structure
      2) Typically made of 2" x 8", 2" x 10", or 2" x 12" boards
   g) Bridging
      1) Small wooden or steel pieces fitted in pairs between the joists
      2) Crossed to reduce movement of the joist and help distribute weight
   h) Subflooring
      1) First layer of material applied over the floor joists

    2) Commonly some type of sheathing material, usually plywood, particle board, or waferboard
    3) Typically has a thickness of at least ½ an inch and is usually ⅝ or ¾ of an inch
    4) Lies under the finish floor
i) Underlayment
    1) Second layer of material attached to the subflooring to strengthen the floor
    2) Usually made of plywood

2. Explain the procedure used to set joists in place. Have students complete JS 5.1.

How are the joists set in place?

a) Attach a sill plate to the foundation or basement walls.
    1) The sill plate is most commonly attached to the foundation with anchor bolts.
    2) Once the sill plate is bolted down, marks can be made on it to indicate the placement of joists.
b) Cut the header joist to length and nail it in place along the outside perimeter of the sill plate; the header joists should be attached standing on the 2-inch edge of the board to form a box sill.
c) Set the stringer joists on edge and fasten them to the header joists using nails or screws.
    1) The joists are spaced an even distance apart, usually 16 inches measuring from the center of one joist to the center of the next.
    2) If a joist will be below a weight-bearing wall, another joist should be placed against it for added strength.
d) When joists meet at a beam, use a metal joist bracket and bolts to attach the ends of the two joists together.
e) Add bridging between joists.
    1) Metal bridging pieces may be used.
    2) Boards may be cut and nailed in place to join the bottom of one joist with the top of the adjacent joist, forming an "X" between the two joists.

3. Describe the procedure for installing subflooring. Hand out AS 5.1.

How is the subflooring installed?

a) Place the sheets of subflooring at 90-degree angle to the joists.
    1) The edge of the sheet should rest on a joist, covering half of the joist.
    2) Another sheet of subflooring can then be joined next to the first sheet, with both sheets attached to the joist.
    3) The sheets of subflooring should be placed with a gap of at least ⅛ of an inch between them to allow for expansion and contraction of the sheets due to temperature changes.
b) Attach the sheets of subflooring to the joists with the fasteners about 8 to 12 inches apart.
    1) Using more fasteners will decrease later "squeaking" from subflooring that is loose.
    2) If extra holding strength is desired, glue may be placed on the tops of the joists before the subflooring is laid down.
c) When placing subflooring on a large floor, stagger or offset the place where the seams come together to give more strength to the floor; this may require cutting a smaller piece to start one strip of subflooring.

4. Emphasize that the floor must be able to support the load of the structure, so load will affect how the flooring is constructed.

How does load determine the type of flooring and subflooring used?

a) Load is the weight carried by any part of a structure.
    1) Dead load

            - (a) Vertical weight of a structure
            - (b) Consists of the total weight of all the permanent parts of the structure, including the foundation, footings, lumber, and electrical and plumbing apparatuses
            - (c) Act constantly
        - 2) Live load
            - (a) Temporary and intermittent
            - (b) Weight or pressure from static and dynamic loads
            - (c) Static load - from anything occupying the structure, such as livestock, equipment, or stored products
            - (d) Dynamic loads - from the operation of equipment like a tractor or handling equipment in the structure
        - 3) Environmental load - caused by natural factors, such as wind, snow, and earthquakes, that result in weight or pressure
    - b) To determine what materials and spacing to use in the flooring, calculate dead load plus the maximum expected live load.
        - 1) Average loads - joists placed 16 inches apart with ¾-inch subflooring
        - 2) Heavy loads
            - (a) Joists spaced only 12 inches apart with 1-inch subflooring
            - (b) Often place two layers of subflooring on the joists for additional strength
                - (1) Increases the thickness of the subflooring to 1½ inches or more
                - (2) Placed at a 90-degree angle from the first layer
            - (c) Require wider joists; 2" × 12" joists can be used if the loads are very heavy
            - (d) Need metal members, large timbers, or combinations of metals, dimensional lumber, and possibly plywood
    - c) Several sources of information are available to help select the right materials and construction for different loads.
        - 1) Tables in construction reference books
        - 2) Manufacturer's recommendations that either are on the material or are made available by retailers
        - 3) Commercially prepared plans

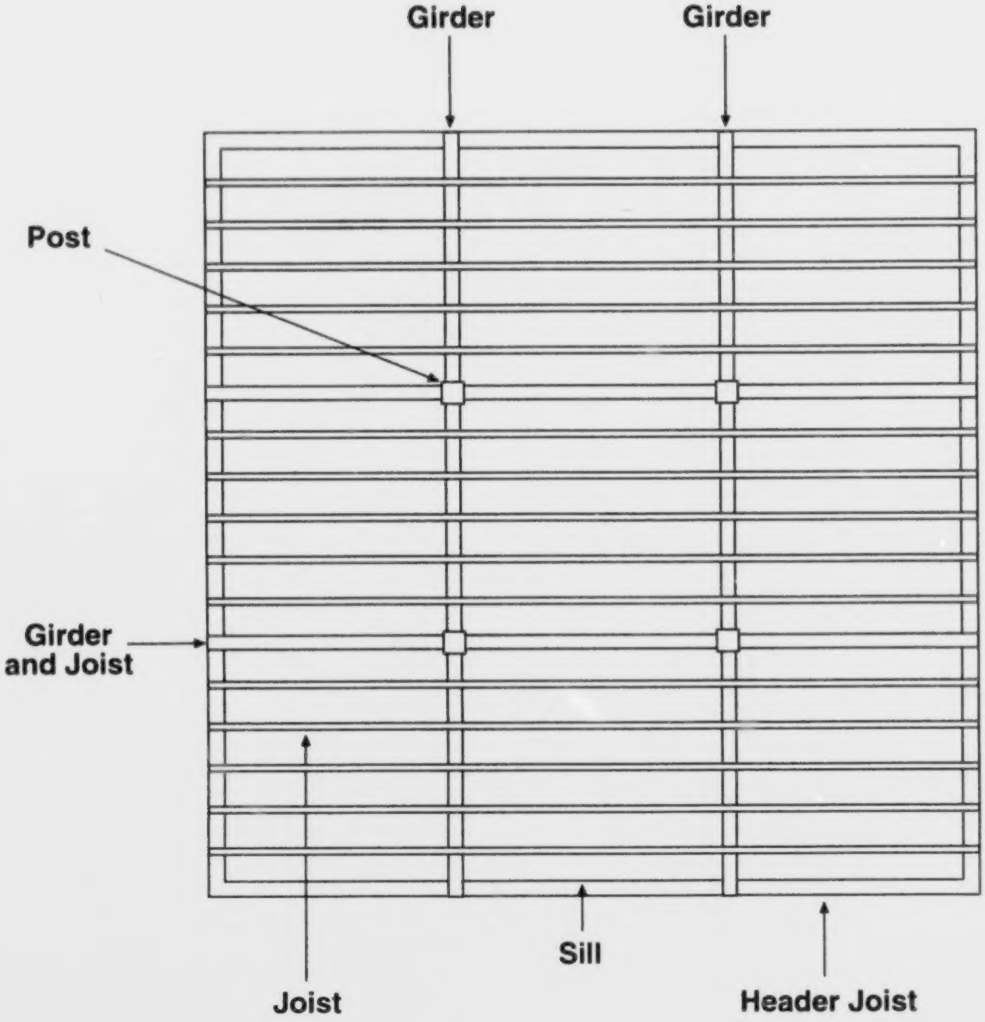
F. *Other Activities*

If possible, schedule a field trip to a construction site where a floor is under construction.

G. *Conclusion*

Floor framing is the structural portion of the building that rests on the concrete foundation and attaches the building to it. Floors have a number of different parts that are constructed to support the building. An extremely important factor to consider when constructing floors is load. Load will determine the size and type of materials needed and their spacing.

H. *Answers to Activity Sheets*


Girder
Girder
Post
Girder and Joist
Joist
Sill
Header Joist

I. ***Answers to Evaluation***

1. b
2. d
3. e
4. f
5. c
6. a
7. c
8. b
9. d
10. d

11. Another joist should be placed next to it for added strength.

12. To allow for expansion and contraction of the sheets due to temperature changes

UNIT III - BUILDING CONSTRUCTION Name ______________________________

Lesson 5: Floors and Subfloors Date ______________________________

EVALUATION

Match the word on the right with the description on the left.

1. _____ Member that rests on the sill and supports the first layer of flooring
2. _____ Member attached to the foundation and the flooring system
3. _____ Member that rests on the sill and attaches to the ends of the joists
4. _____ Pieces placed between adjacent joists
5. _____ Member that supports the joists across the span of the flooring
6. _____ Layer of material placed on top of joists

a. Subflooring
b. Joist
c. Girder
d. Sill plate
e. Header joist
f. Bridging

Circle the letter that corresponds to the best answer.

7. Snow contributes to:

   a. Live loads.
   b. Dead loads.
   c. Environmental loads.
   d. Dynamic loads.

8. What is the typical spacing between joists?

   a. 15 inches
   b. 16 inches
   c. 17 inches
   d. 18 inches

9. Subflooring should be attached:

   a. Parallel to the joists.
   b. Between the joists.
   c. At the ends of the joists.
   d. At a 90-degree angle to the joists.

10. Which of the following might be done to help support heavy loads on a structure?

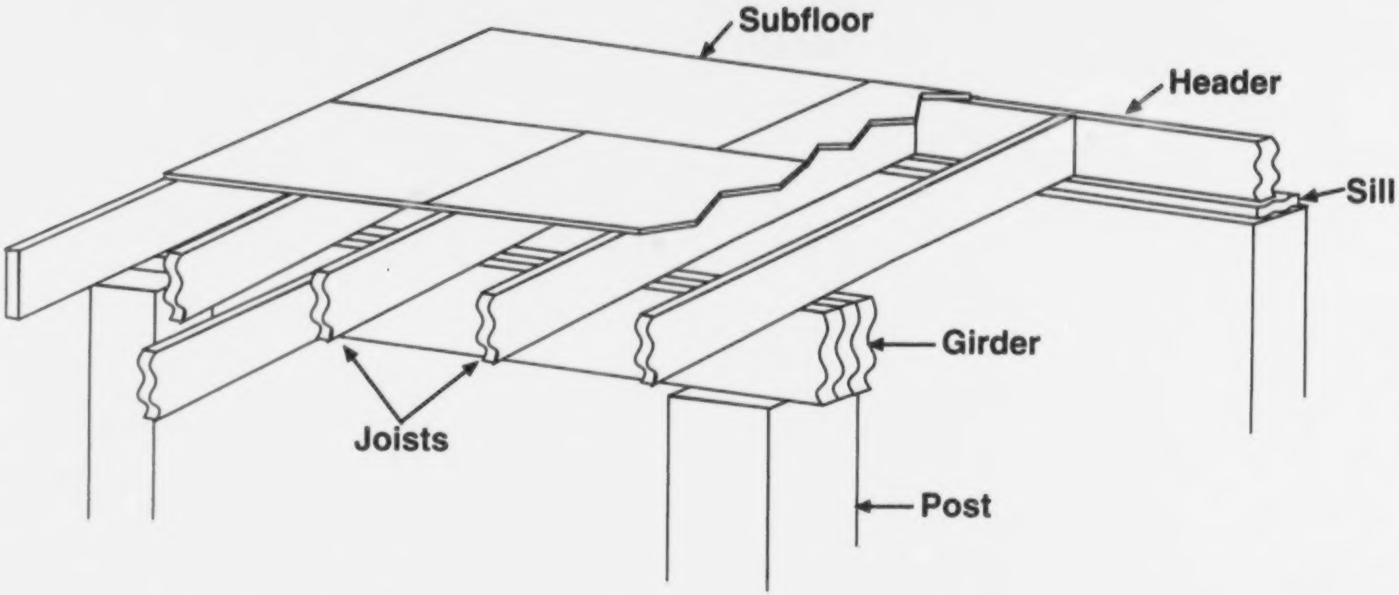
    a. Spacing joists 20 inches apart
    b. Using subflooring ½ an inch thick
    c. Using 2" × 6" boards for joists
    d. Adding a second layer of subflooring

Complete the following short answer questions.

11. What should be done if a joist will be below a weight-bearing wall?

12. Why should sheets of subflooring be placed with a gap between them?

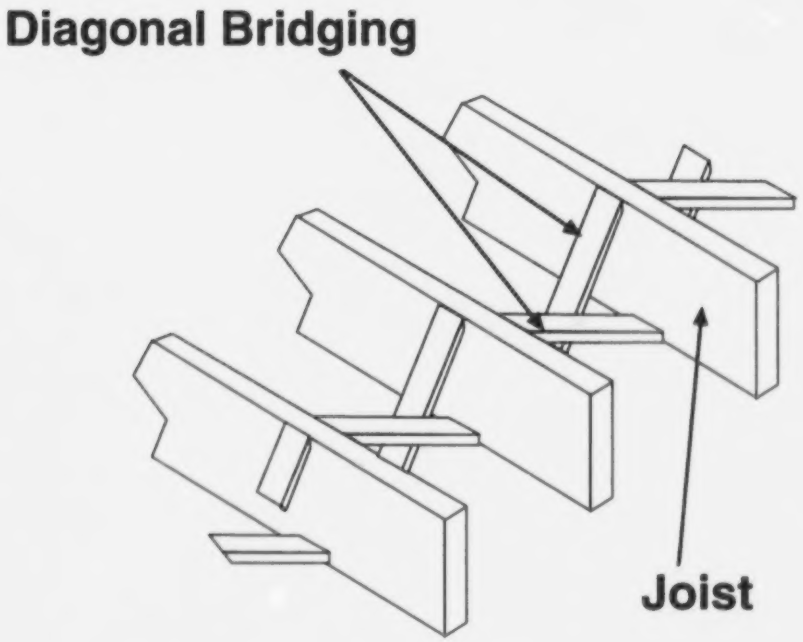
Parts of a Floor


Subfloor
Header
Sill
Girder
Joists
Post

Agricultural Structures, III-59

TM 5.1

Bridging


Diagonal Bridging
Joist

Lesson 5: Floors and Subfloors Name ____________________________

Diagramming Flooring

Objective: Diagram floor layout.

Using the information below, sketch the floor described showing an overhead view without decking. Use a scale of ¼" = 1'.

- The floor is to be 24 feet by 24 feet.
- The sill is a 2" × 6" that is anchor bolted to the foundation every four feet.
- The joists and joist headers are 2" × 10" material.
- Girders are positioned so that no span extends more than eight feet without support. Support posts for the girders are to be placed every eight feet.
- Bridging is not required for this project.

Name ______________________________

Joist Layout

Objective: Lay out joists for floor framing.

Materials and Equipment:

10 8-foot 2" x 8" boards
2 10-foot 2" x 8" boards
16d duplex head nails
Circular or radial arm saw
Hammer
Tape measure

Procedure:

For this activity, assume that the sill plate is in place and that the box sill would be connected to the sill plate.

1. Use the 10-foot boards for header joists.
2. Cut the joists to 7 feet, 9 inches in length.
3. Nail the two outside joists to the header joists, making a box.
4. Mark the header joist to indicate the placement of the remaining joists. The joists should be placed on 16-inch centers (16 inches from the center of one joist to the center of the next).
5. Nail the joists between the header joists on both ends, using two nails in each end.

UNIT III - BUILDING CONSTRUCTION

Lesson 6: Walls

Competency/Objective: Describe the purposes of walls, types of walls, supports, and siding used in agricultural buildings.

Study Questions

1. **What are three purposes of walls?**
2. **What are different types of wall construction?**
3. **What are the components of stud frame walls?**
4. **How is a wood stud frame wall constructed?**
5. **What types of siding are used in agricultural structures?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit III.
2. Transparency Masters
    - a) TM 6.1: Pole Frame Construction
    - b) TM 6.2: Stud Frame Construction
    - c) TM 6.3: Components of a Frame Wall
3. Activity Sheet
    - a) AS 6.1: Wall Construction

Lesson 6: Walls

TEACHING PROCEDURES

A. ***Review***

Lesson 5 discussed various aspects of constructing a floor for a structure. Walls are another important aspect of most construction projects. Lesson 6 describes the basic functions of walls as well as the different methods of construction and their components.

B. ***Motivation***

Make models of a post and beam wall and a wood frame wall using balsa wood, small strips of pine, or Popsicle sticks. These models should be small enough to handle easily. Pass them around and discuss the differences.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Ask students if they can list three purposes of walls. Discuss these purposes with the students.

   What are three purposes of walls?

   a) Support vertical loads
   b) Resist lateral loads
   c) Provide protection from the weather

2. Use TM 6.1 and 6.2 to illustrate the differences between pole and stud frame construction. Discuss the differences between the two.

   What are different types of wall construction?

   a) Pole frame construction
      1) Poles or posts form the main structural members of the wall.
      2) Horizontal pieces of dimensional lumber called laths or girts are attached to the poles.
      3) Siding is placed vertically on the structure by attaching it to the laths.
   b) Stud frame construction - Walls are built using studs, which are the vertical wall members that provide the main support for the wall.

3. Show students TM 6.3. Discuss the different components of a frame wall.

   What are the components of stud frame walls?

   a) Top plate - horizontal member at the top of the wall on which the trusses or rafters rest
   b) Sole plate - structural member forming the bottom of the wall to which the studs are nailed
   c) Stud - vertical wall member that provides the main support for the wall
   d) Diagonal brace - member that adds to the rigidity of the wall, making it stronger; used in construction to keep the walls square and vertical
   e) Header - horizontal piece found above openings for doors and windows that provides support for loads over the opening

   - f) Jack stud or cripple stud - stud that is shorter than full length used below windows and above windows and doors
   - g) Trimmer stud - vertical framing member that forms the sides of door and window openings and supports the header
   - h) Rough sill - horizontal framing member attached to the top of the jack studs to form a rough base for a window
   - i) Blocking - wooden blocks that are used to fill in the space between framing members, providing support
   - j) Siding - material placed on the outside of a building to seal and enclose the building
   - k) Interior covering - material placed on the inside of the wall

4. Ask students to describe light wood construction. Hand out AS 6.1.

   How is a wood stud frame wall constructed?

   - a) Walls are typically constructed one wall or section of a wall at a time, with the wall laying flat on the ground.
   - b) Determine the length of the wall and cut the top and bottom plates to that length.
   - c) Nail the studs between the top and bottom plate using two nails at each end of the stud.
     - 1) They are spaced an equal distance apart, usually 16 inches.
     - 2) Buildings with less weight on the walls are sometimes constructed with the studs 24 inches apart.
   - d) Nail double studs side by side at the corners of a building.
   - e) Diagonal braces and blocking attached between the studs add to the rigidity of the wall, making it stronger.
   - f) When the wall is finished, stand it upright and attach it to the foundation or subfloor using nails or bolts.
   - g) Nail walls together at the corners.
   - h) Remove diagonal braces.
   - i) If the wall has windows or doors, they require additional components.
     - 1) Window framing usually requires a header as well as extra support from trimmer boards at the sides of the opening.
     - 2) Window openings generally also use jack studs and a rough sill.
     - 3) Door framing involves the use of a header, extra supports on the sides, and sometimes jack studs.

5. Showing the class some samples or pictures clipped from sales literature will help when discussing this lesson's content.

   What types of siding are used in agricultural structures?

   - a) Dimensional lumber
     - 1) 1" × 12" boards or other similar sizes
     - 2) Accepts paint or stains readily, allowing customization
     - 3) Degrades due to weather, although it can be treated to be weather resistant, increasing the life of the lumber
   - b) Exterior plywood
     - 1) Sold in larger sheets, so fewer seams will exist, aiding in insulating
     - 2) Easier to apply than dimensional lumber
     - 3) Cheaper than other forms
     - 4) Not as attractive
   - c) Hardboard sheathing, or Masonite
     - 1) Sold in sheets that come in a number of colors
     - 2) Provides some insulation
     - 3) Relatively easy to apply
     - 4) Somewhat brittle and does not easily withstand stress
   - d) Metal siding

    1) Commonly made of galvanized steel or aluminum
    2) Sheets that are normally at least 3 feet wide and 8, 10, or 12 feet long
    3) Fewer seams, allowing for better insulation and weatherproofing
    4) Lasts for a very long time
    5) Can be painted but not stained

e) Vinyl siding
    1) Consists of strips that overlap, sealing the building
    2) Available in a variety of colors
    3) Relatively long life
    4) More expensive than other types of siding

f) Masonry products like bricks and cinder blocks
    1) Decorative
    2) Last for an extremely long time
    3) Moderate cost
    4) More difficult to apply

g) Fiberglass, glass, and plastics
    1) Used in certain situations, such as a greenhouse
    2) Purchased with varying levels of clarity, from totally clear to mostly opaque

F. *Other Activities*

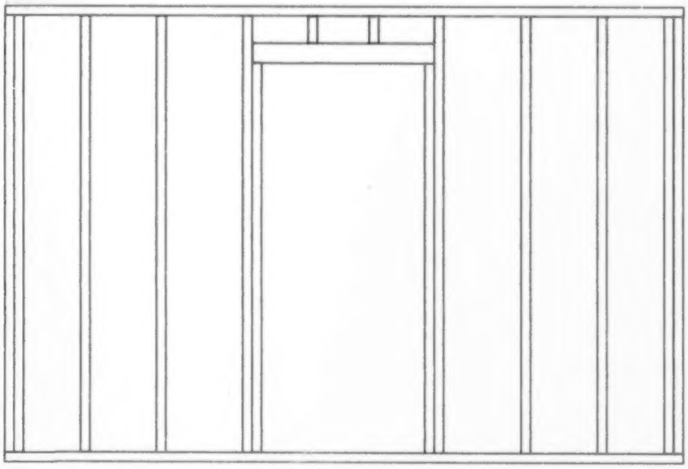
Ask students to identify which types of siding are commonly used in the community for different types of structures. Discuss why a particular type of siding would be used for certain applications.

G. *Conclusion*

Wall construction is critical to a building's structural soundness and function. Walls serve three purposes: supporting vertical loads, resisting lateral loads, and providing protection from the weather. The two common types of wall construction for agricultural structures are pole frame construction and stud frame construction. Once a wall is constructed, a number of different types of siding can be used.

H. *Answers to Activity Sheet*

1. Answers will vary, but should look something like the following image.



2. Two 2" X 4" boards, 7' long - door frame
   Two 2" X 4" boards, 3' long - door frame

Twelve 2" X 4" boards, 7'9" long - studs
Two 2" x 4" boards, 12' long - top and bottom plate
Six 4" X 8" sheets of plywood - siding
Three 2" X 4" boards, 9" long - cripple studs

I. *Answers to Evaluation*

1. g
2. c
3. a
4. b
5. d
6. f
7. e
8. a
9. c
10. d
11. Pole frame and stud frame
12. To support vertical loads, resist lateral loads, and provide protection from the weather

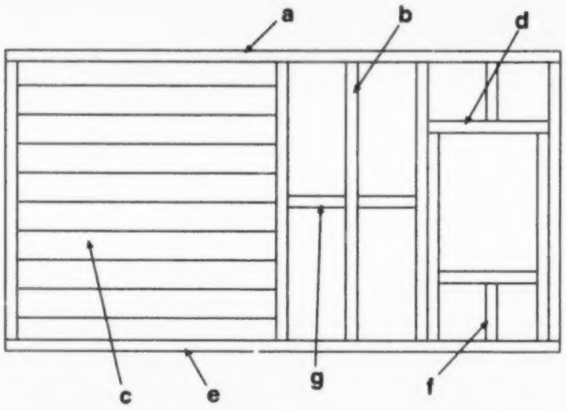
UNIT III - BUILDING CONSTRUCTION Name ____________________

Lesson 6: Walls Date ____________________

EVALUATION

Write the letter in the blank next to the name of the structural member pictured.

1. ____ Blocking piece
2. ____ Siding
3. ____ Top plate
4. ____ Stud
5. ____ Header
6. ____ Jack stud
7. ____ Sole plate



Complete the following short answer questions.

8. A piece of lumber nailed temporarily on a wall to stabilize it is called a:

   a. Diagonal brace.
   b. Stud.
   c. Siding.
   d. Top plate.

9. Studs are usually placed ______ inches apart.

   a. 14
   b. 15
   c. 16
   d. 17

10. A disadvantage of metal siding is that it:

   a. Is not fireproof.
   b. Is sold in large sheets.
   c. Has more seams when applied.
   d. Cannot be stained.

Complete the following short answer questions.

11. What are two different types of wall construction?

    a.

    b.

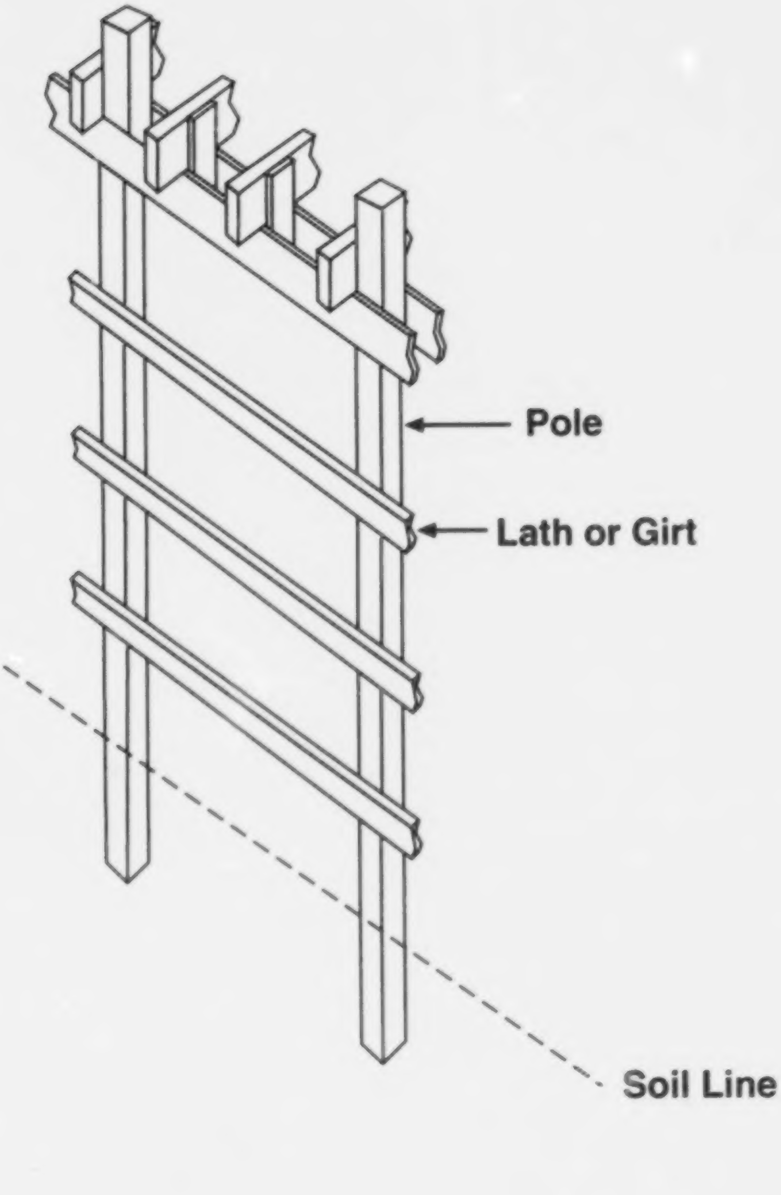
12. What are the three purposes of walls?

    a.

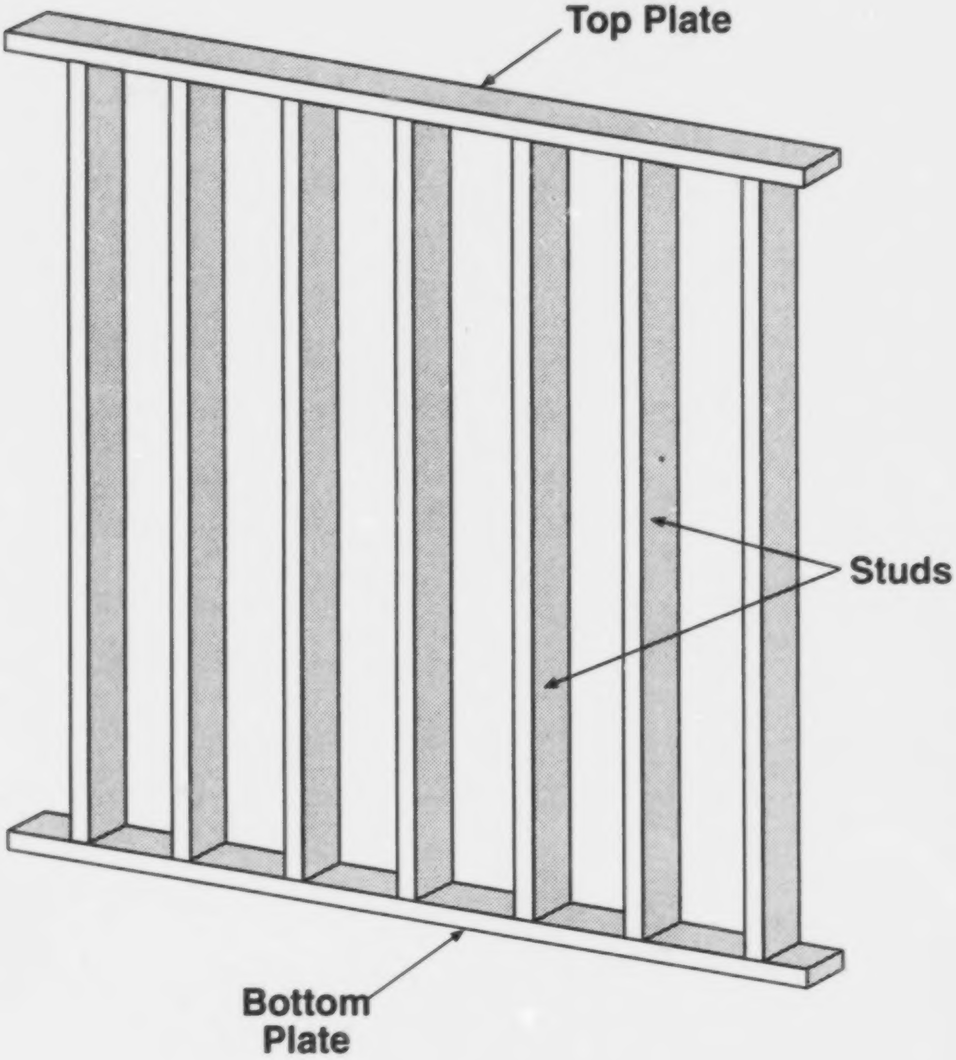
    b.

    c.

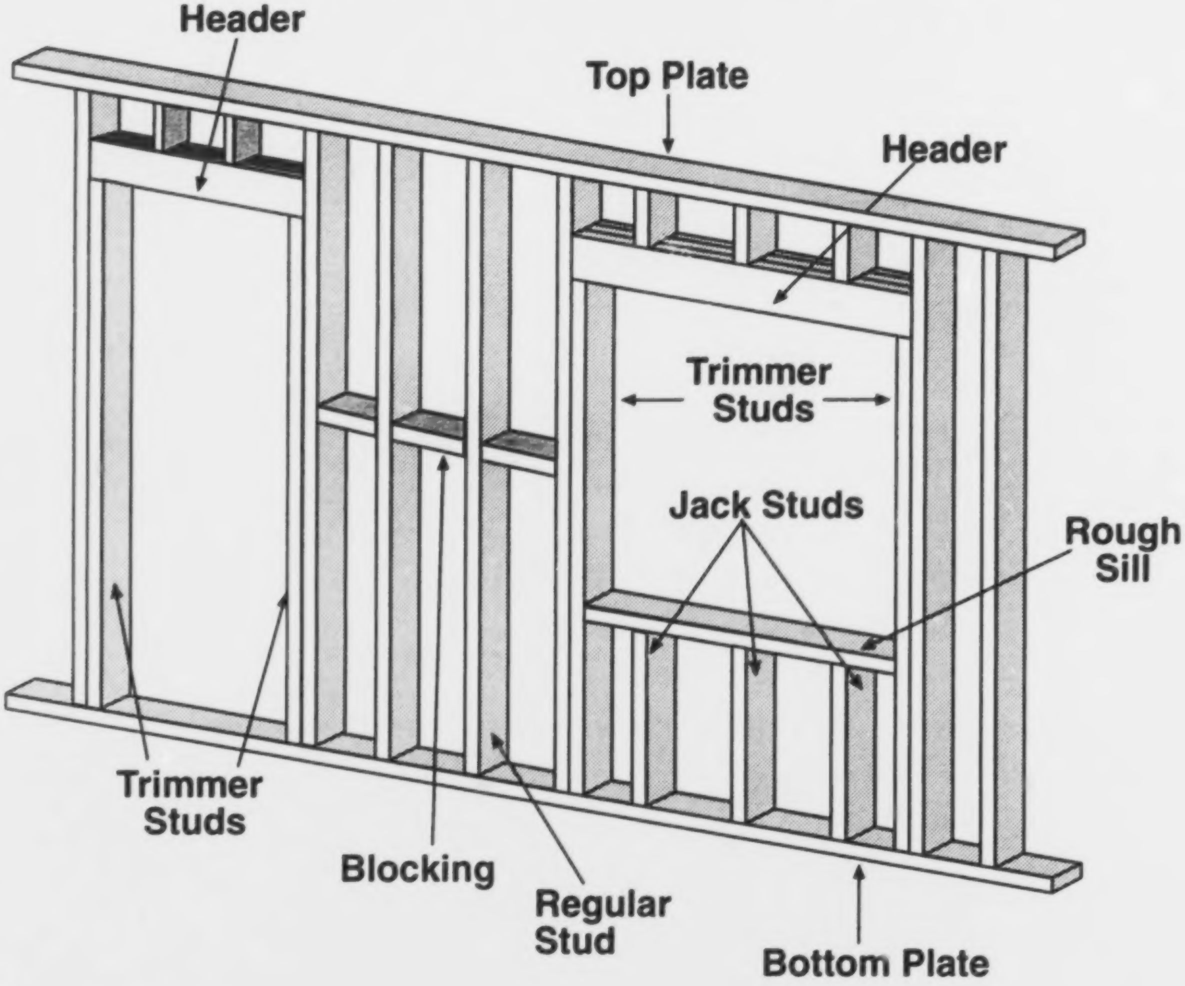
Pole Frame Construction


Pole
Lath or Girt
Soil Line

Stud Frame Construction


Top Plate
Studs
Bottom Plate

Components of a Frame Wall


Header
Top Plate
Header
Trimmer Studs
Jack Studs
Rough Sill
Trimmer Studs
Blocking
Regular Stud
Bottom Plate

Agricultural Structures, III-79

TM 6.3

Lesson 6: Walls Name ____________________

Wall Construction

Objective: Plan the construction of a wall.

Suppose you are constructing a wall that is 8 feet high and 12 feet long. Determine the materials required and the exact dimensions needed. The wall is to be sided on both sides with 4' × 8' plywood sheets and constructed of 2" × 4" boards. It will have a door consisting of a rough opening 3 feet by 7 feet in the exact middle of the wall. Put double studs at each end for strength.

1. First, sketch the wall as it would be constructed.

2. List the materials needed, indicating their uses.

UNIT III - BUILDING CONSTRUCTION

Lesson 7: Roof Support Systems

***Competency/Objective*:** Select a roof support system.

Study Questions

1. **What is the difference between a truss and a rafter?**
2. **How is a roof system selected?**
3. **What is pitch?**
4. **How is the pitch of a roof figured?**
5. **What are the parts of a rafter?**
6. **How is a rafter laid out?**
7. **What is a top plate?**
8. **How is a top plate constructed?**
9. **How is a truss ordered?**
10. **What are the types of roof styles?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit III.
2. Transparency Masters
    a) TM 7.1: Sample Truss
    b) TM 7.2: Rafters
    c) TM 7.3: Pitch
    d) TM 7.4: Parts of a Rafter
    e) TM 7.5: Rafter Table
    f) TM 7.6: Rafter Cuts
    g) TM 7.7: Roof Styles
3. Job Sheet
    a) JS 7.1: Rafter Layout

UNIT III - BUILDING CONSTRUCTION

Lesson 7: Roof Support Systems

TEACHING PROCEDURES

A. *Review*

Lesson 6 discussed the functions of walls, their different methods of construction, and their components. Most agricultural structures will also require a roof. A vital part of a roof is its support system. This lesson explores aspects of roof support systems and various options available as well. The process of laying out a rafter is also described.

B. *Motivation*

Prepare a model of a truss made of 2" × 4" boards, balsa, thin strips of pine, etc. Discuss the parts of the model with the class.

C. *Assignment*

D. *Supervised Study*

E. *Discussion*

1. If the model prepared for the motivation is available, use it to illustrate what a truss looks like. TMs 7.1 and 7.2 can also be used to show the differences between a truss and a rafter. Discuss these differences.

   What is the difference between a truss and a rafter?

   a) Truss
      1) Structural assembly of lightweight material consisting of connected triangles used to create a system designed to support heavy loads over a considerable span
      2) Made of wood, wood products, metal, or a combination of any or all of these materials
      3) Vary in design depending on the needs of the structure
      4) Nearly always prefabricated units designed for a specific structure that are transported to the construction site and mechanically placed in position

   b) Rafter
      1) Structural member that spans from a wall's top plate to the ridge board of the roof
      2) Generally describes a site-built truss-type system

2. Discuss load as an aspect of selecting a roof system. Point out that due to liability, more and more people are turning to professionals for information about load and roof support systems. Discuss the economics of labor and time involved in building a roof system.

   How is a roof system selected?

   a) Ability to safely support roof loads
      1) The choice of a roof system will vary depending on the weather of the geographical area, which determines wind and snow loads.
      2) Different materials and roof designs have varying load capacities.

   b) Economics of cost and labor
      1) Truss companies will build to order and generally provide this service at a cost equal to or less than the cost of manufacturing a system on site.
      2) Roof support systems of smaller structures may be built on site at a savings.

    3) The labor involved in cutting and assembling systems must be considered.

3. Ask students to define pitch. Use TM 7.3 to illustrate pitch. Again, the model suggested in the motivation section could be used as a tool for initiating this discussion.

What is pitch?

a) Pitch is the steepness of a roof.
b) To calculate pitch, the rise and run for the roof must be known.
    1) Rise - vertical distance from the top plate to the ridge
    2) Run - horizontal distance covered by one rafter from the outside edge of the top plate to the exact center of the ridge
    3) Span - Total distance from the outside edge of one wall to the outside edge of the other wall; equal to twice the run
c) Pitch may be defined as a fraction that is a ratio of the rise to the span.
d) Pitch may also be expressed as slope in a ratio of the number of inches of rise per foot of run.
    1) Example: 6:12, meaning six inches of elevation for every twelve inches of length
    2) Shown using an inverted right triangle and the accompanying rise and run numbers

4. Write these formulas on the blackboard and discuss them. Have students work some sample problems to understand how pitch is calculated.

How is the pitch of a roof figured?

$$Pitch = \frac{Rise}{2 \times Run}$$

5. Use TM 7.4 to illustrate the parts of a rafter. Discuss the different parts with the class.

What are the parts of a rafter?

a) Tail (overhang) - part of the rafter that forms the part of the roof from the side of the building to the end of the roof
b) Tail cut - cut made at the end of the rafter, parallel with the wall
c) Seat cut (bird's mouth) - notch cut out of a rafter that allows the rafter to be seated on the top plate
d) Ridge cut (plumb cut) - cut made at the end of the rafter that fits against the ridge board and allows the rafter to fit flush against the ridge

6. A carpenter's framing square is almost essential to teach this part of the lesson. Show the class the rafter table on the framing square and discuss how it is used. Obtain three or four feet of 2" × 8" material and make the tail, ridge, and seat cuts. Have all the students observe how the numbers on the square were used to determine the exact places to cut. TMs 7.5 and 7.6 can also be used to illustrate the rafter table and how to make the cuts on the rafter. Hand out JS 7.1.

How is a rafter laid out?

a) Determine the length of the rafter.
    1) Locate the number that indicates the rise per foot of run on the blade of the framing square.
    2) In the rafter table beneath this number is a number indicating the length of a common rafter per foot of run.
    3) Multiply this second number by the number of feet of run.

        4) Add the length of the tail and subtract one-half the thickness of the ridge board; round as needed to the nearest 1/4 inch.
        5) Divide by 12 to find the length in feet and inches.
    b) Make the tail cut at the end of the board that overhangs the structure.
        1) Mark the measuring line in the center of the rafter material and then measure and mark the correct length of the rafter along the line.
        2) Place the square on the material and align the body's number 12 with the top of the board.
        3) Pivot the framing square until the number indicating the rise on the tongue aligns to the top edge of the board; the outside edge of the tongue must be even with the mark made along the measuring line.
        4) Mark the tail cut along the outside edge of the tongue and cut the rafter.
    c) Make the ridge cut at the opposite end of the material.
        1) The ridge cut is made in the same manner as the tail cut.
        2) Take care to align the outside edge of the tongue with the mark indicating the length of the rafter found at this end of the measuring line.
    d) Make the seat cut.
        1) Measure the length of the tail and mark this point on the measuring line.
        2) Lay the material with the edge to be cut facing the opposite direction.
        3) Place the framing square on the material with the body pointing to the right and the tongue pointing up.
        4) Align the inside edge of the tongue to the mark indicating the length of the tail; adjust the tongue until the rise corresponds with the edge of the board and the number 12 is on the inside edge of the body on the edge of the board.
        5) Mark and cut out the wedge-shaped section.

7. Use TM 7.2 to show what a top plate looks like. Discuss the function and location of this structural member.

What is a top plate?

a) A top plate is a wall member that is usually made of the same material as a wall's studs.
b) It is attached to the top of the studs.
c) Rafter seat cuts fit over the top plate, connecting the wall to the roof support system.

8. Discuss how to construct a top plate.

How is a top plate constructed?

a) Dimensional lumber of the same size used for the wall studs is attached to the tops of the studs.
b) Often a second piece of the same material is attached to increase strength and stability; the joints of the layers should not overlap.

9. Ask students to list information a truss manufacturer would need to know if trusses were ordered from the company. Discuss the information given below.

How is a truss ordered?

a) Supply the truss manufacturer with a copy of the building's plans, which will provide all the technical information needed.
b) Tell the builder the type of roofing material that will be used.
c) Provide the desired delivery date, time, and exact directions to building site.

10. Ask students to list some roof styles used for agricultural structures. Use TM 7.7 while describing the characteristics of the different styles.

What are the types of roof styles?

a) Shed
  1) Only a single pitch
  2) Usually found on smaller structures of 2,000 square feet or less
  3) Inexpensive to construct
  4) Simple to frame and install
  5) Able to resist winds well because the slope of the roof is relatively shallow

b) Hip
  1) Attractive appearance
  2) Difficult to frame and install
  3) Poor ventilation of attic areas

c) Gable
  1) Often used for agricultural structures
  2) Relatively inexpensive and easy to frame
  3) May be extremely wind resistant if the pitch of the roof is not too steep

d) Gambrel
  1) Two different pitches, with the top pitch being approximately 30 degrees and the bottom pitch around 60 degrees
  2) Used for barns, because the design provides the advantage of spacious overhead room for storage
  3) Expensive
  4) More difficult to construct
  5) Less resistant to damage from winds

e) Mansard
  1) Attractive appearance
  2) Leaks more easily because of the shallow pitch of the roof

f) Quonset
  1) No flat surfaces
  2) Forms a semicircle with an arching roof
  3) Usually sold as a package and are therefore easy to construct

g) Gothic/arched
  1) Two curving arches meeting at a point
  2) Structures
    (a) Similar to Quonset buildings in that they have no walls
    (b) Other types of buildings, such as barns, that do have distinct walls
  3) Strong roof
  4) Large storage volume.

F. *Other Activities*

Have students research and prepare reports on truss systems. They should describe (and diagram, if possible) some of the different styles and configurations available.

G. *Conclusion*

Roof support systems consisting of trusses or rafters are vital parts of agricultural structures. Truss systems are generally prefabricated and brought to the building site; rafter systems are commonly built on site. Either system may work well if loads are carefully considered, and the choice of which system to use is often based on the economics of cost and labor.

H. *Answers to Activity Sheet*

I. *Answers to Evaluation*

1. d
2. b

3. c
4. a
5. c

6. Answers may include any two of the following: shed, hip, gable, gambrel, mansard, Quonset, and Gothic/arched.

7. To increase strength and stability

8. Answers may include any of the following: supply the truss manufacturer with a copy of the building's plans, tell the builder the type of roofing material that will be used, and provide the desired delivery date, time, and exact directions to building site.

9. The ability to safely support roof loads and the economics of cost and labor
10. ⅓

UNIT III - BUILDING CONSTRUCTION Name ______________________________

Lesson 7: Roof Support Systems Date ______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. The structural member that connects the wall to the roof support system is the:

   a. Ridge board.
   b. Rafter.
   c. Tail.
   d. Top plate.

2. Which of the following is the part of the rafter that allows the rafter to be attached to the wall?

   a. Ridge cut
   b. Seat cut
   c. Tail cut
   d. Bird's tail

3. Pitch may be expressed as:

   a. The ratio of the number of inches of run per foot of rise.
   b. The rise divided by the run.
   c. The ratio of the number of inches of rise per foot of run.
   d. The run divided by the rise.

4. The structural member that spans from the wall to the ridge board of the roof is the:

   a. Rafter
   b. Tail
   c. Seat
   d. Truss

5. What is the first step in determining the length of the rafter?

   a. Find the number on the rafter table indicating the length of a common rafter per foot of run.
   b. Locate the number that indicates the run per foot of rise on the blade of the framing square.
   c. Locate the number that indicates the rise per foot of run on the blade of the framing square.
   d. Find the number on the rafter table indicating the length of a common rafter per foot of rise.

Complete the following short answer questions.

6. What are two types of roofs commonly used for agricultural structures?

   a.

   b.

7. What is one thing that must be done when ordering a truss?

8. When constructing a top plate, why would it be doubled?

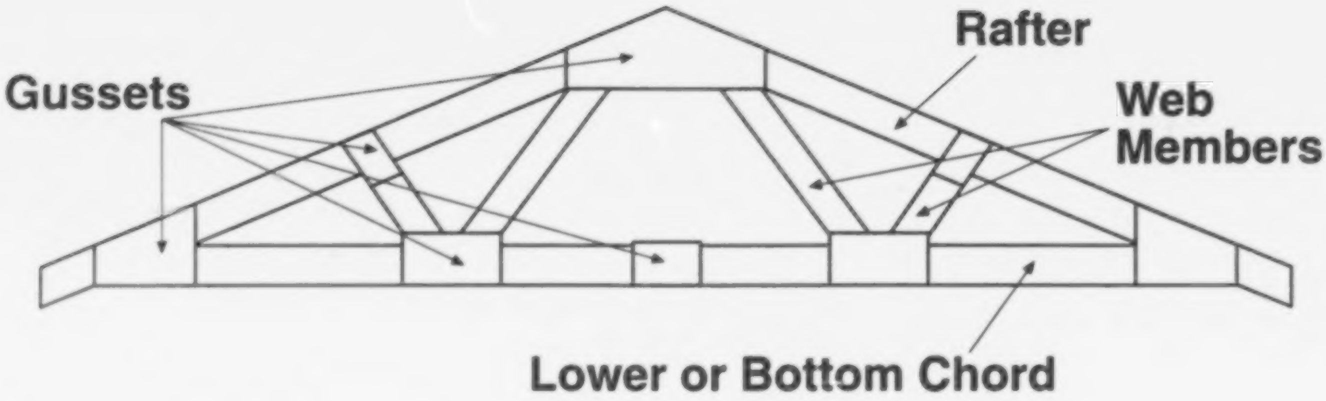
9. What are two things that must be considered when selecting a roof system?

   a.

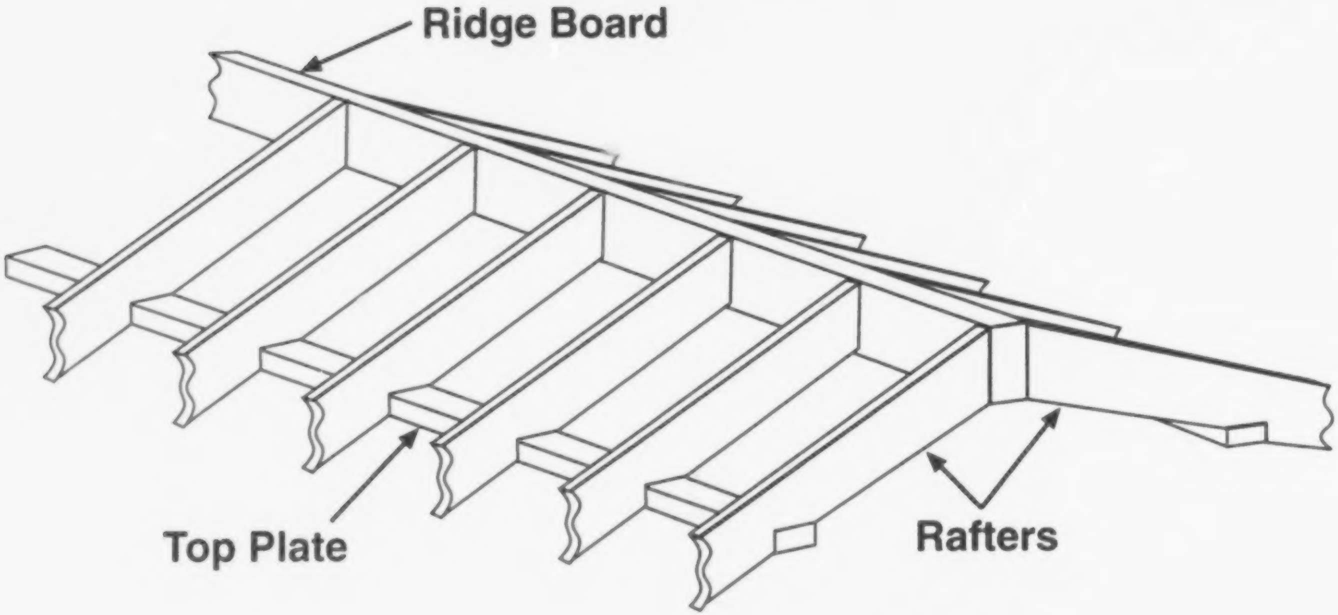
   b.

10. What is the pitch of a roof with a rise of 8 feet and a run of 12 feet?

Sample Truss


Gussets
Rafter
Web Members
Lower or Bottom Chord

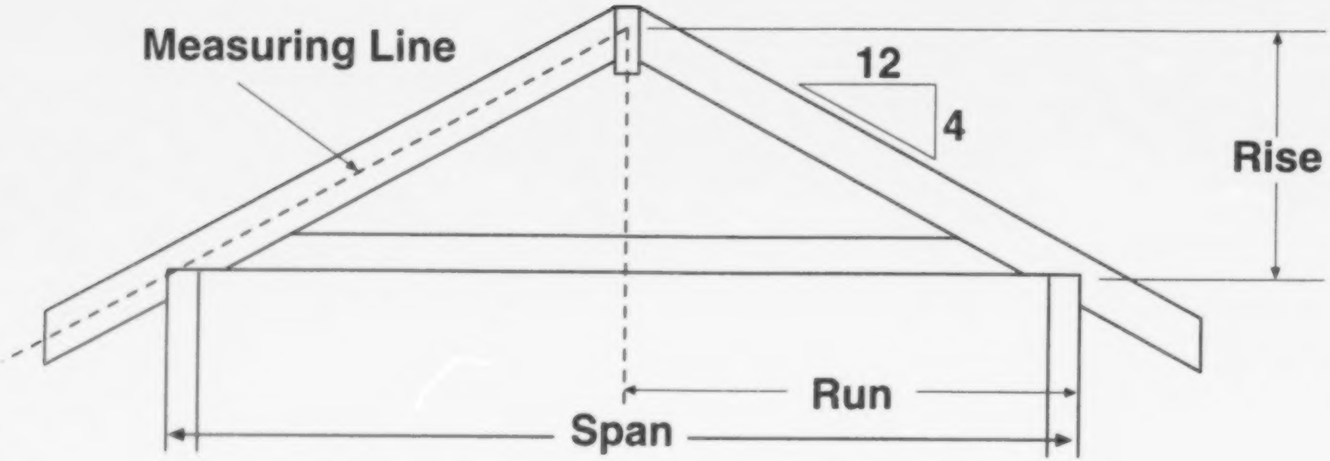
Rafters


Ridge Board
Top Plate
Rafters

166

165

Pitch


Measuring Line
12
4
Rise
Run
Span

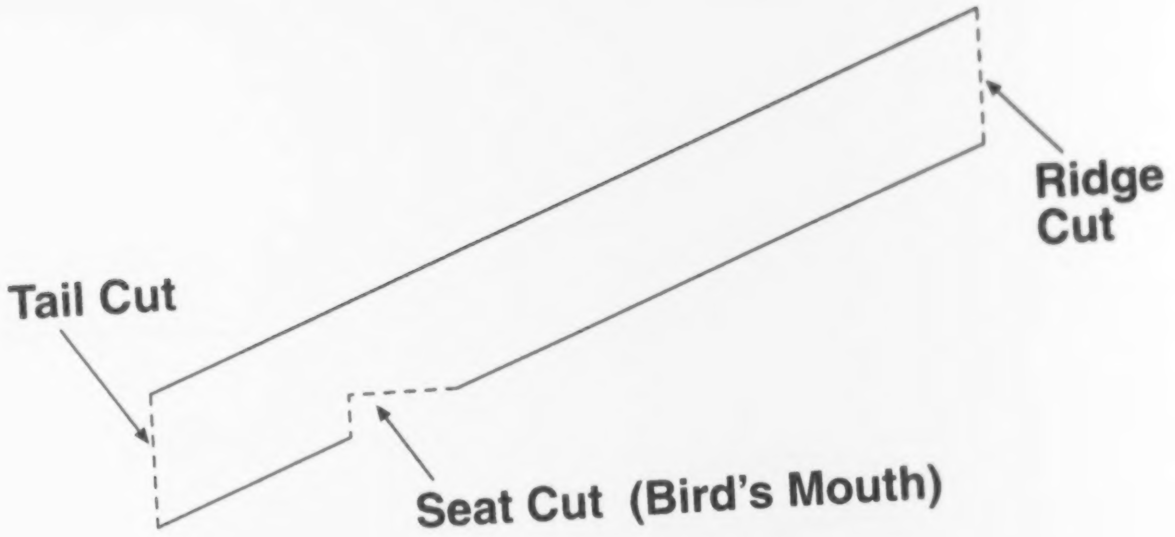
Span = 24 feet
Rise = 4 feet
Run = 12 feet

$$\text{Pitch} = \frac{\text{Rise}}{2 \times \text{Run}}$$

What is the pitch? What is the slope?

Agricultural Structures, III-97

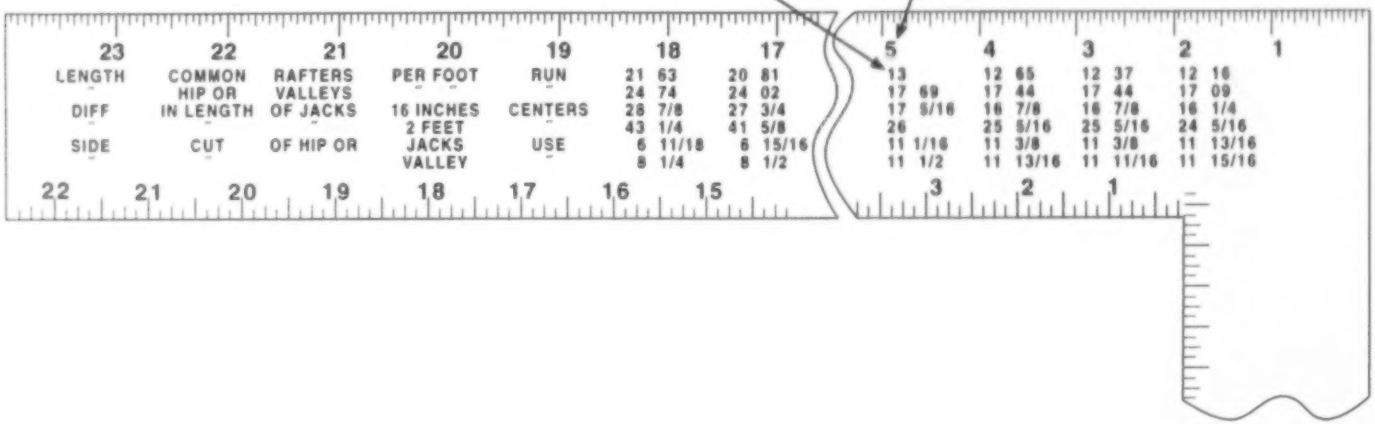
Parts of a Rafter


Ridge Cut
Tail Cut
Seat Cut (Bird's Mouth)

Agricultural Structures, III-99

TM 7.4

Rafter Table


23
22
21
20
19
18
17
5
4
3
2
1
LENGTH
DIFF
SIDE
COMMON
HIP OR
IN LENGTH
CUT
RAFTERS
VALLEYS
OF JACKS
OF HIP OR
PER FOOT
16 INCHES
2 FEET
JACKS
VALLEY
RUN
CENTERS
USE
21 63
24 74
28 7/8
43 1/4
6 11/16
8 1/4
20 81
24 02
27 3/4
41 5/8
6 15/16
8 1/2
13
17 69
17 5/16
26
11 1/16
11 1/2
12 65
17 44
16 7/8
25 5/16
11 3/8
11 13/16
12 37
17 44
16 7/8
25 5/16
11 3/8
11 11/16
12 16
17 09
16 1/4
24 5/16
11 13/16
11 15/16
22
21
20
19
18
17
16
15
3
2
1

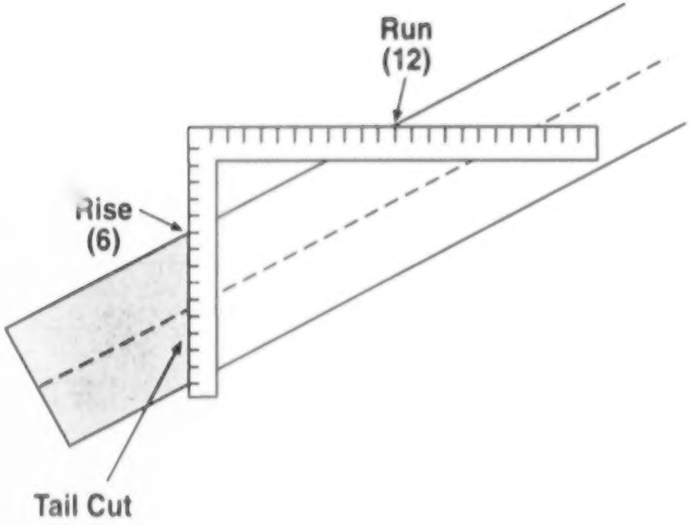
Rafter Length Per Foot of Run

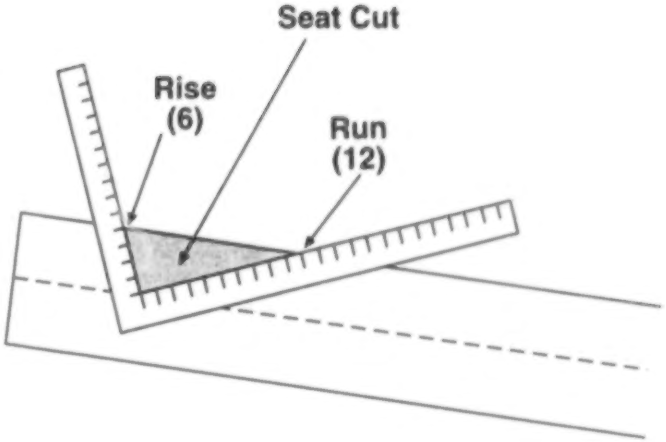
Rise Per Foot of Run

Agricultural Structures, III-101

TM 7.5

Rafter Cuts

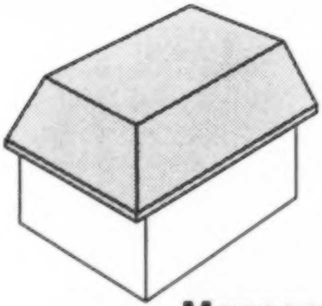

Run
(12)
Rise
(6)
Tail Cut

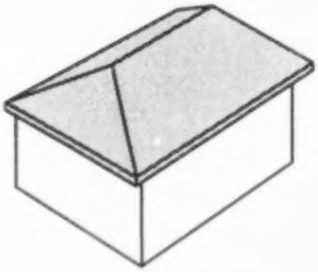

Seat Cut
Rise
(6)
Run
(12)

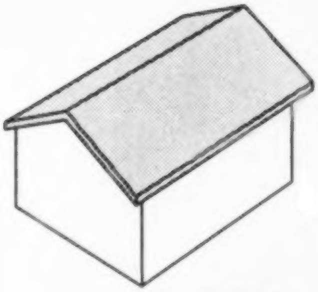
Agricultural Structures, III-103

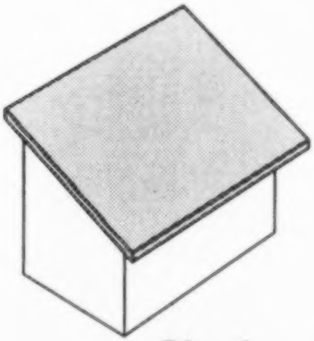
TM 7.7

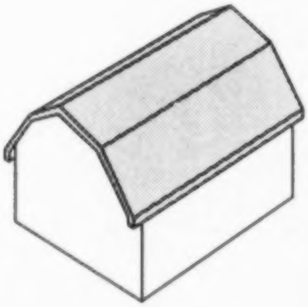
Roof Styles

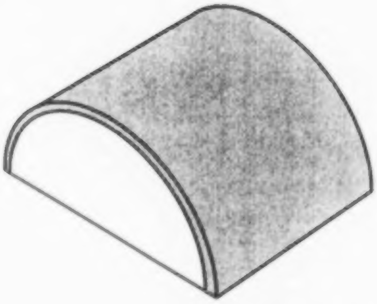

Mansard

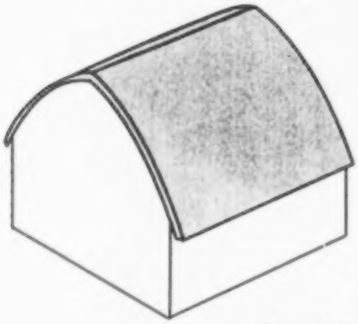

Hip


Gable


Shed


Gambrel


Quonset


Gothic

Name ______________________________

Rafter Layout

Objective: Lay out a rafter.

Materials and Equipment:

Pencil and paper
Carpenter's framing square
Boards, strips of construction paper, cardboard, or rolls of fax paper

Procedure:

For this problem, lay out a rafter for a building that has a span of 10 feet and a rise of 5 feet. Using rafter material provided, lay out the ridge cut, seat cut, and tail cut. Assume that the overhang is 12 inches long. The slope is 6:12, because the rafter will have 6 inches of rise for every foot of run.

1. Using the rafter material, begin at one end by marking the ridge cut. For this exercise, you will use the step method of using a framing square.
2. Place the square so that the 6-inch mark on the tongue is on the edge of the square and the same side of the tongue crosses at the corner of the board.
3. Align the 12-inch mark on the body with the edge of the board to form the correct angle for the ridge cut.
4. Mark a line along the edge of the tongue of the square.
5. Where the 12-inch mark rests on the edge of the board, make a small mark. This mark will be used in the next step.
6. Line up the 6-inch mark on the tongue with the mark you just made.
7. Line up the square so the 12-inch mark on the body is at the edge of the board.
8. Make another small mark where the 12-inch mark meets the edge.
9. Repeat steps 6 to 8 four more times.
10. Draw a line across the board next to the tongue of the square to mark the seat cut.
11. From this line, measure another 12 inches down the board and mark the location for the overhang.
12. At this mark, repeat steps 6 to 8 again to indicate the tail cut.
13. On the seat cut line, measure 1½ inches up from the bottom and make a mark on the line to indicate the depth of a seat cut (commonly the thickness of a 2" board).
14. At the mark, use the framing square to make a 90-degree angle to the edge of the board. Mark the line to form the seat cut.
15. If a ridge board is used, ¾ of an inch needs to be cut off the ridge cut (half the thickness of a 2" board) at the same angle as the ridge cut.

UNIT III - BUILDING CONSTRUCTION

Lesson 8: Roofing Materials

***Competency/Objective*:** Select roofing materials.

Study Questions

1. **What different types of roofing materials are available?**
2. **What are the advantages and disadvantages of different types of roofing materials?**
3. **What are the structural components of a roof?**
4. **How are different types of roofs attached?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit III.
2. Transparency Master
    a) TM 8.1: Structural Components of Roofs
    b) TM 8.2: Applying the Starter Course
    c) TM 8.3: Three-Tab Shingle Application
    d) TM 8.4: Applying Cap Shingles
3. Activity Sheet
    a) AS 8.1: Applying Roofing Materials

TEACHING PROCEDURES

A. ***Review***

Lesson 7 discussed the roof support systems found in agricultural structures. The support system is only part of the roof, however. Lesson 9 explores the roofing materials that are commonly used, their advantages or disadvantages, and how roofing materials are used in roof construction.

B. ***Motivation***

Display a few different types of shingles, a piece of roll roofing, and a few sections of metal roofing (both galvanized and painted). Identify the different materials and ask students to name places they have seen these materials in use.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Discuss the different materials listed below with the class. If the samples suggested in the motivation section are available, use them to illustrate the various types. If not, use clippings from magazines as examples of these products.

   What different types of roofing products are available?

   a) Asphalt - roll or shingle form
   b) Fiberglass - shingles
   c) Metal - galvanized or painted

2. Discuss the advantages or disadvantages of these materials in comparison to each other.

   What are the advantages and disadvantages of different types of roofing materials?

   a) Asphalt
      1) Advantages
         (a) Lower in cost than either metal roofing or fiberglass shingles
         (b) Roll asphalt - simple installation
      2) Disadvantages
         (a) Roll asphalt - least attractive roofing material
         (b) Relatively brief life span of 15 to 25 years under normal conditions
         (c) Burns readily
   b) Fiberglass shingles
      1) Advantage
         (a) Moderate in cost
         (b) Long life span, around 30 years
      2) Disadvantage - flammable
   c) Galvanized metal
      1) Advantages
         (a) Relatively inexpensive
         (b) Very fire resistant
         (c) Very long life span of 50 years or longer

        (d) Very durable material
    2) Disadvantage
        (a) Plain silver appearance, which may not make it suitable for all uses
        (b) Noise caused by rain or hail striking the roof
d) Painted metal
    1) Advantages
        (a) Fire resistant
        (b) Long life span of 30 or more years
    2) Disadvantages - generally more expensive than asphalt shingles, galvanized metal, or fiberglass roofing

3. Use TM 8.1 as an aid in explaining the structural parts of a roof system. Discuss the structural components of roofs.

What are the structural components of a roof?

a) Rafters or trusses
b) For roll or shingle asphalt or fiberglass shingles, a solid decking system to which the roofing material is attached
    1) The decking may be either some form of sheathing material, such as plywood or oriented-strand board, or dimensional lumber (usually 3/4" thick).
    2) The decking is nailed or screwed over the top of the roof support system.
c) For metal roofing, a purlin system to which the roofing material is attached
    1) Purlins are pieces of dimensional lumber, commonly 1" × 4", in varying lengths.
    2) They are nailed perpendicular to the rafters.
    3) The spacing of the purlins is dependent on many variables, such as the roof span, the strength of the material used for the purlins, and pitch.

4. Collect some examples of common roofing materials to display while discussing this part of the lesson. Describe how different types of roofs are attached, using TMs 8.2, 8.3, and 8.4 to illustrate shingling. Have students work on AS 8.1. Enough of the model shingles to complete the activity should be photocopied and given to the students before beginning the activity.

How are different types of roofs attached?

a) Roofing materials in roll or shingle form
    1) They are fastened with galvanized or aluminum nails.
        (a) The nails are usually 1¾ inches long.
        (b) They have a large, flat head to hold the material securely and resist tearing the shingle.
    2) Shingles may also come with an adhesive on them to help secure them to the decking.
    3) The first step in attaching shingles is to nail or staple a layer of building felt, or underlayment, in place.
        (a) Building felt is a tar-soaked fabric that will repel water.
        (b) Place the felt across the length of the roof horizontally starting at the bottom, with successive layers overlapping about 4 inches.
        (c) Apply a drip edge to the bottom and sides of the roof over the underlayment to prevent moisture from seeping under the underlayment.
    4) Apply the shingles to the roof, starting at the bottom with each successive layer or course of shingles overlapping the layers below.
    5) The first layer of shingles is made of half shingles.
        (a) For three-tab shingles, cut the shingle lengthwise at the top of the tabs.
        (b) Cut the first shingle in the starter course to a length of 30 inches to offset the end with the first course of full shingles.
        (c) Place the long edge of the shingle along the edge of the roof.

- (d) Attach the shingles as square to the edge as possible; use a hand level to make sure the first layer is level.
- (e) Apply nails in the sealer strip, with one nail on each end of the shingle and above each weep.

6) Lay the remaining courses.
  - (a) The starter course will be completely covered by the next course of shingles.
  - (b) The shingles in each remaining course overlap the previous course halfway, or just above the top of the weeps.
  - (c) Stagger the weeps of each course equally from the previous course to form a brick-type pattern.
  - (d) Cut the first shingle in each course at six-inch increments, producing shingles that are 30, 24, 18, 12, and 6 inches long.
  - (e) Lay out these shingles at the edge of the roof in sequence.
    - (1) Start with a full shingle and continue across the roof with full shingles.
    - (2) Cut the last shingle in the course even with the side of the roof.
    - (3) Start the second course with a 30-inch shingle, the third with a 24-inch shingle, etc., creating a pattern that is repeated every six rows.
  - (f) The cut-off material may be used at the other end of a course.
  - (g) Any pieces over 12 inches long may be used on the peak of the roof.

7) At the peak of the roof, finish the cap.
  - (a) One method is to cut three-tab shingles into three sections and lay them over the top courses on each side of the ridge.
  - (b) Another method involves using special cap shingles at the peak of the roof.
  - (c) Overlap the shingles to prevent rain from getting under them.
  - (d) The direction of overlap depends on the normal wind direction.

b) Metal roofing

1) Metal roofing materials are attached with ring shank screws or nails with an attached neoprene or lead washer.
  - (a) They are generally 2½ inches in length.
  - (b) Overlap the ribbing running the length of the material.
  - (c) Place the nails or screws through the ridges of the roofing material, not in the flat areas.
  - (d) The placement of fasteners will vary depending on the type of ribbing; the manufacturer's recommendations should always be followed.

2) Aluminum and galvanized metal materials should not be used together, since the combination will result in an electrolyte reaction that causes corrosion.

F. *Other Activities*

1. Have students collect pictures of the roofs of different agricultural structures. Have the class assemble these into a scrapbook that can be used as a reference in the future.

2. Divide the class into groups; have each group prepare a report about one of the basic types of roofing materials covered in this lesson. They could provide information on variations in quality, life span warranties among similar products, and manufacturer's recommendations for their use. The groups should be prepared to present their findings to the class.

3. Have students watch "Application of Three-Tab Composition Shingles" (15 min.), available from MVRC.

G. *Conclusion*

Roofing materials are made from asphalt, fiberglass, or metal. Each of these materials has advantages and disadvantages. The structural components of the roof and how the roofing material is attached will vary depending on the materials used.

H. *Answers to Activity Sheet*

1. To allow the water to drain off without leaking
2. By determining how many square feet needed to be covered. Shingles are sold in squares, and one square is enough to cover 100 square feet.
3. The starter course determines how straight and square each course above will be.

I. ***Answers to Evaluation***

1. b
2. c
3. a
4. d
5. b
6. Shingles and roll roofing
7. Galvanized metals
8. Shingles or roll roofing
9. To nail or staple a layer of building felt in place

Name ______________________________

Lesson 8: Roofing Materials

Date ______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. The roofing material that generally has the longest life span is:
   - a. Painted metal.
   - b. Galvanized metal.
   - c. Asphalt.
   - d. Fiberglass.

2. Which roofing material costs the least?
   - a. Painted metal
   - b. Galvanized metal
   - c. Asphalt
   - d. Fiberglass

3. Purlins are nailed:
   - a. Perpendicular to the rafters.
   - b. Diagonal to the ridge board.
   - c. Parallel to the rafters.
   - d. Perpendicular to the ridge board.

4. The roofing material that generally has the shortest life span is:
   - a. Painted metal.
   - b. Galvanized metal.
   - c. Asphalt.
   - d. Fiberglass.

5. Where should the first row of shingles be laid?
   - a. At the top of the roof
   - b. At the bottom of the roof
   - c. At the left edge of the roof
   - d. At the right edge of the roof

Complete the following short answer questions.

6. What two forms does asphalt roofing material come in?

   a.

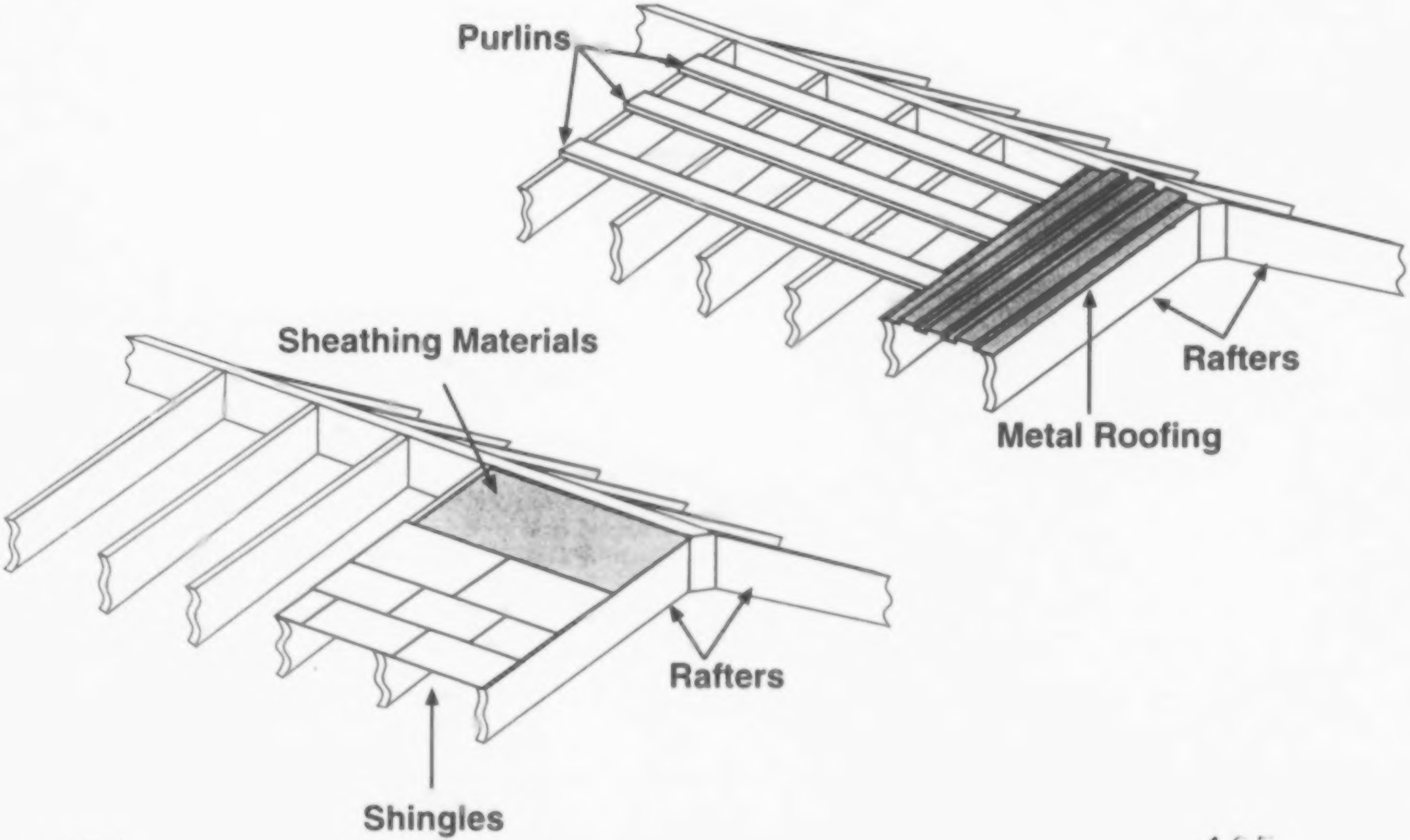
   b.

7. What type of roofing material cannot be attached with aluminum fasteners?

8. What types of roofing material must be applied over a solid decking?

9. What is the first step in attaching roofing shingles?

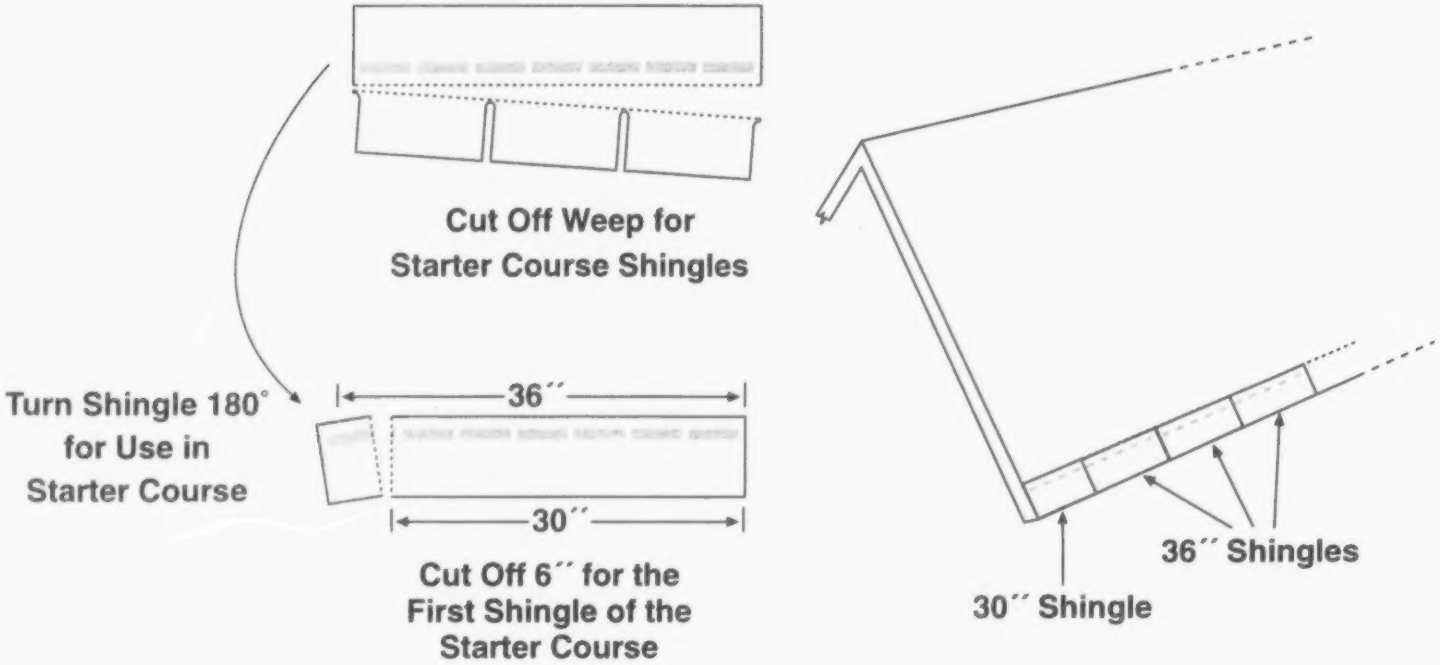
Structural Components of Roofs


Purlins
Sheathing Materials
Rafters
Metal Roofing
Rafters
Shingles

Agricultural Structures, III-117

TM 8.1

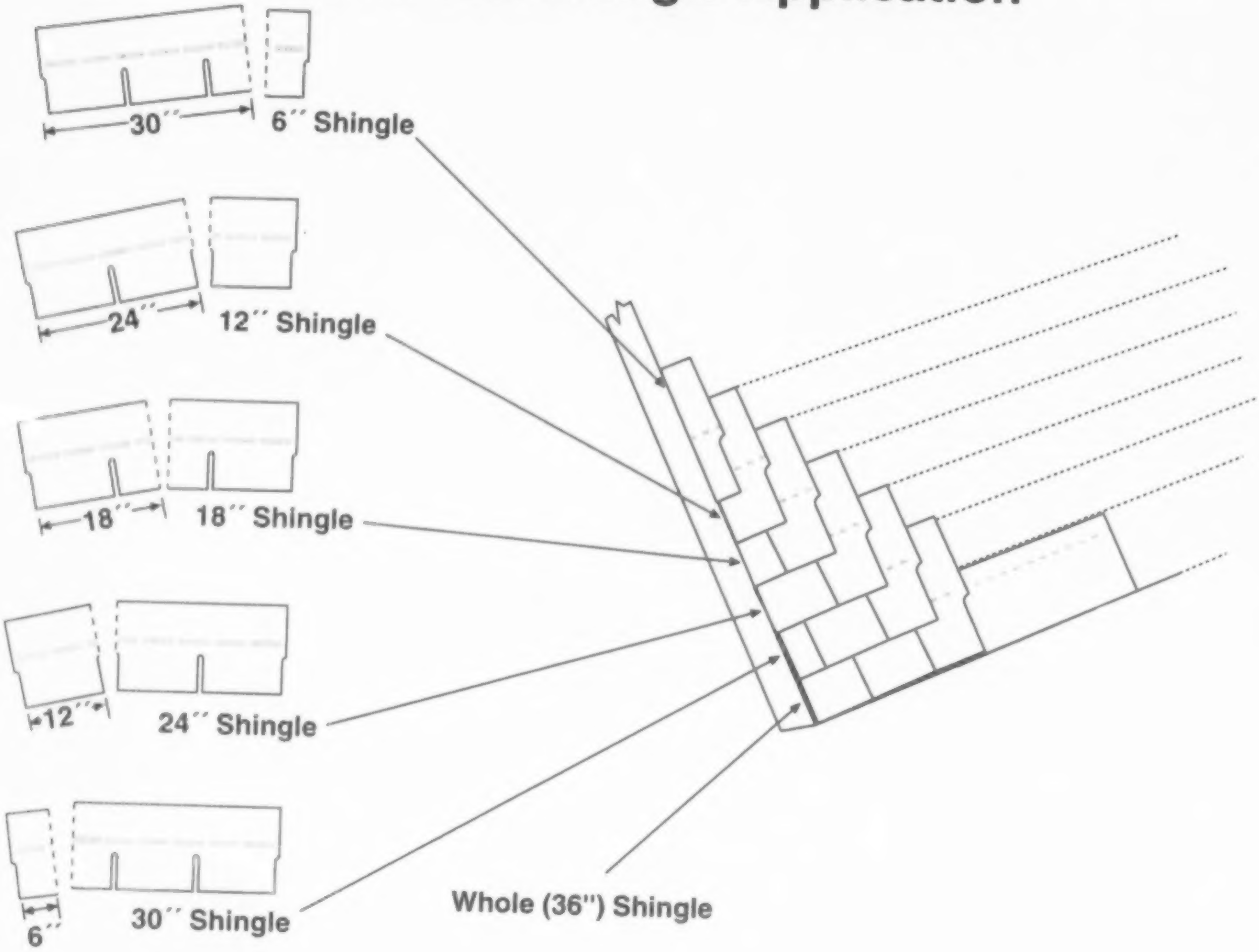
Applying the Starter Course


Cut Off Weep for
Starter Course Shingles
Turn Shingle 180°
for Use in
Starter Course
36´´
30´´
Cut Off 6´´ for the
First Shingle of the
Starter Course
36´´ Shingles
30´´ Shingle

Agricultural Structures, III-119

TM 8.2

Three-Tab Shingle Application

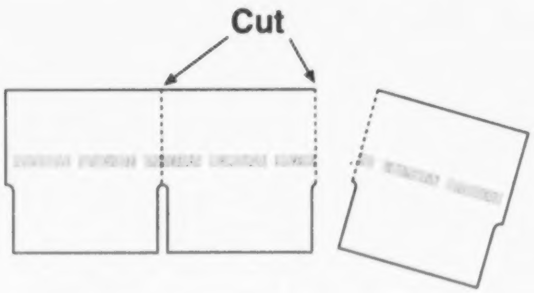

30´´
6´´ Shingle
24´´
12´´ Shingle
18´´
18´´ Shingle
12´´
24´´ Shingle
6´´
30´´ Shingle
Whole (36") Shingle

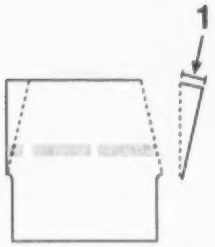
Agricultural Structures, III-121

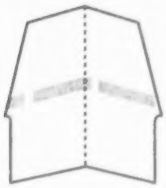
TM 8.3

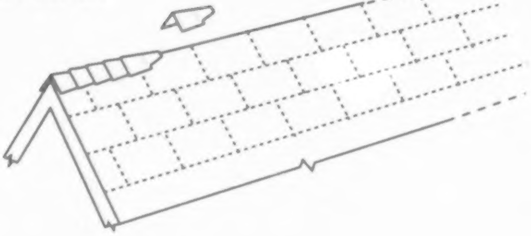
TM 8.4

Applying Cap Shingles




1´´
Trim 1´´ Off Both Sides


Fold Down the Middle


Edges of Cap Shingles Will Overlap the Last Course on Each Side of the Roof
Overlap Cap Shingles

Lesson 8: Roofing Materials

Name ______________________________

Applying Roofing Materials

Objective: Apply different types of roofing materials.

Materials and Equipment:

Classroom or shop tables
Paper models of shingles

Procedure:

For this activity, assume that one edge of the table is the bottom of a roof. Place the model shingles on the "roof's" surface, starting at the bottom. The paper shingles are 9 inches long, ¼ the size of a real shingle. All cuts in the shingle must be scaled to the appropriate length.

1. Make half shingles by cutting the shingle at the top of the tabs (Figure 1.1). Cut first shingle to 7½ inches in length and place the long, uncut side of the shingle along the bottom edge.

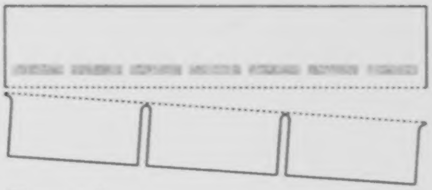


Figure 1.1

2. Apply the starter course to the table using tape at the top of the shingle. Make sure the shingles are as square to the edge as possible.
3. Make partial shingles at the end of each course by cutting the last shingle as appropriate.
4. Lay the first full course over the starter course. Apply the entire course with tape, making sure the shingles are square.
5. For the next course, cut 1½ inches off the first shingle.
6. Apply the course, laying the shingles halfway over the first course (just above the weeps).
7. Lay the rest of the courses across the table surface, staggering the shingles in a brick-type pattern (Figure 1.2). Keep the shingles as square to the edge as possible.

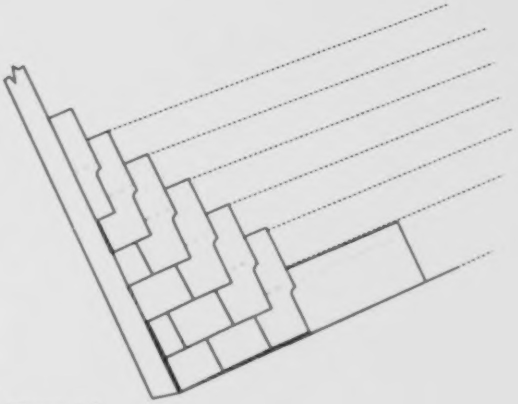


Figure 1.2

8. At the peak, apply the cap. Cut three-tab shingles into three sections at the weeps to use as cap shingles. Angle trim each cap shingle from the top of the shingle to the top of the weep (Figure 1.3).

9. Place the cap shingles over the top course. They should overlap each other as if the wind is coming from the left side of the table.

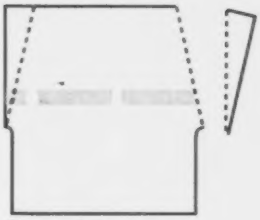


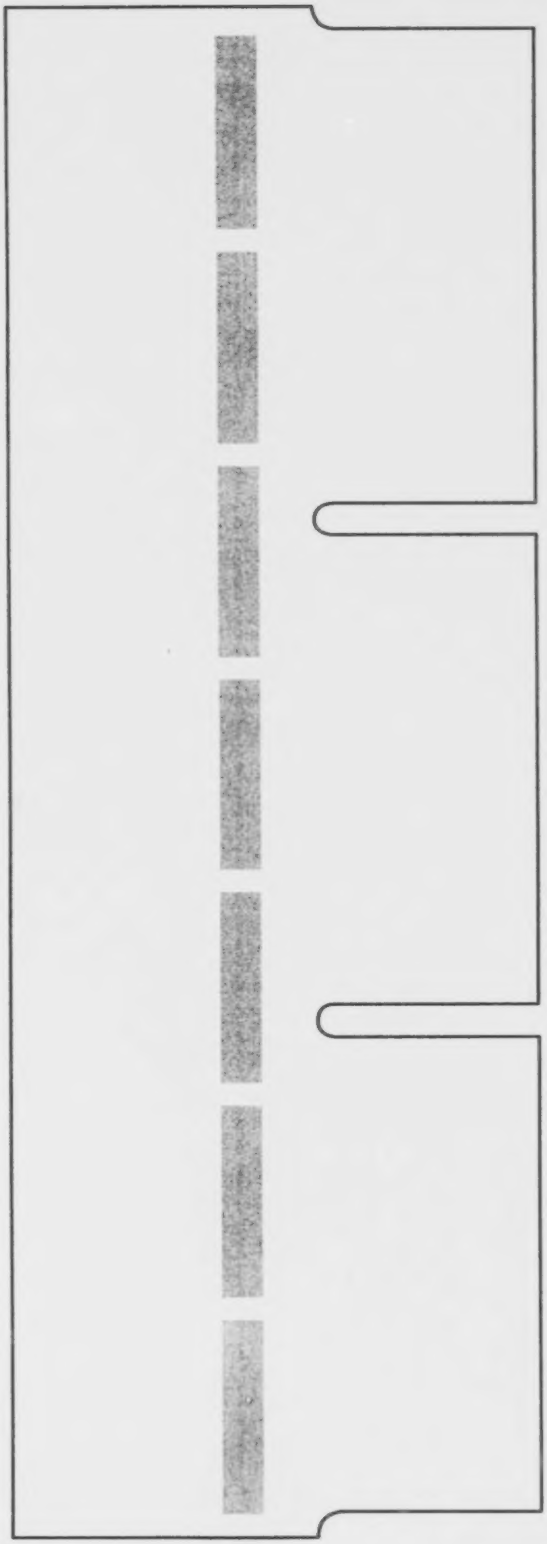
Figure 1.3

Key Questions:

1. Why are the layers of shingles overlapped?

2. How would you determine how many shingles to buy for a construction project?

3. Why is it important to make sure the starter course is straight and square?



Lesson 9: Heating, Cooling, and Ventilation

Competency/Objective: Identify factors affecting the heating, cooling, and ventilation of agricultural structures.

Study Questions

1. **Why insulate buildings?**
2. **What are the different types and methods of insulation?**
3. **Why is ventilation important?**
4. **What type of heating systems are available?**
5. **When is passive solar heating feasible?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit III.
2. Activity Sheet
   a) AS 9.1: Heating, Cooling, and Ventilation Needs

TEACHING PROCEDURES

A. *Review*

Lesson 8 discussed roofing materials and how they are used for agricultural structures. Lesson 9 introduces the basics of heating, cooling, and ventilation. While not all agricultural buildings will require elaborate insulation, heating, or ventilation, these factors are important to consider, because they may affect the design and construction of a structure.

B. *Motivation*

Discuss how temperature and weather conditions affect agricultural structures and their uses. Topics for discussion include how heat or cold can affect the livestock being housed in a structure and the effect of freezing on plumbing.

C. *Assignment*

D. *Supervised Study*

E. *Discussion*

1. Ask students why insulation is used in buildings. Discuss the purposes of insulation with students.

   Why insulate buildings?

   a) Insulation enhances a structure's ability to regulate temperature.
   b) A particular insulation's ability to resist the transfer of heat is expressed mathematically as an R-value.

2. Have students list some types of insulation they have seen. Discuss the materials and the methods of insulation used. If possible, bring in some samples of insulating material and show them to the class.

   What are the different types and methods of insulation?

   a) Types of materials
      1) Natural/organic - generally cheaper but do not insulate as well
         (a) Cotton
         (b) Cellulose
         (c) Shredded Bark
         (d) Shavings
         (e) Sawdust
         (f) Straw
      2) Manufactured - higher R-value per inch of thickness
         (a) Fiberglass
         (b) Rockwool
         (c) Expanded mica
         (d) Fiber board
         (e) Cellular glass
         (f) Expanded polystyrene
         (g) Expanded polyurethane

        (h) Urea formaldehyde
        (i) Polyisocyanurate
    b) Methods of insulation
        1) Blanket
            (a) Consists of wide rolls of material, often with foil covering on one or both sides and an insulating material like fiberglass in the middle
            (b) Used for insulating metal buildings and covering large sections of walls
            (c) Usually stapled to the inside walls of the structure on wide, flat surfaces
        2) Batt
            (a) Provided in rolls of material in precut sections, usually 8 feet in length and 16 inches wide with a thickness of 4 to 6 inches, although the exact size of this material varies with the intended application
            (b) Fits between the studs in the walls or other framework in structures
            (c) Fastened in place with staples
        3) Rigid
            (a) Available in the form of sheathing (usually 4' × 8') in varying thicknesses
            (b) May be made of a number of materials but is most commonly Styrofoam
            (c) Often covered with foil on one or both sides
            (d) Usually nailed in place on the outside walls of a structure before siding is applied
        4) Fill
            (a) Comes in a loose form
            (b) Generally made of fiberglass or expanded mica
            (c) May be emptied from bags where needed or mechanically blown in place through a large hose that feeds the material to the desired place
            (d) Sometimes mixed with chemicals to make it adhere to a horizontal or overhead surface and then blown into place

3. Discuss the importance of ventilation with the class.

Why is ventilation important?

a) Controls temperature
b) Controls inside moisture levels
c) Reduces the growth of microorganisms
d) Diminishes odor problems
e) Prevents the accumulation of dangerous gases

4. Ask student to list some types of heating systems they have seen. Discuss the types of systems commonly used in agricultural structures

What types of heating systems are available?

a) Radiant
    1) Heat passes through the air until it comes into contact with an object and passes on its energy as heat.
    2) The system will not heat objects out of its path.
    3) Gas or electricity may be used to power these systems.
Floor
    1) The systems are usually designed to heat specific areas.
    2) Hot water pipes or electric elements are buried just below the surface of the floor.
    3) These systems may be powered by electricity, natural gas, or ground-source heat pumps
Unit
    1) These heaters are used to heat the air in a general area of a structure.
    2) They often use fans to circulate the air after heating it.

- 3) Unit heaters may be powered by a variety of fuels, such as propane, natural gas, or electricity.

d) Boilers and furnaces
- 1) Boilers and furnaces are large commercial appliances utilizing a system of pipes, ducts, or vents to transfer heat to where it is needed.
  - (a) Boilers - hot water pumped to radiators
  - (b) Furnaces - heat air and blow it through ductwork to the rest of the building
- 2) They may be powered by fuels such as propane, natural gas, electricity, or wood.

5. Discuss when passive solar heating might be used. Have students complete AS 9.1.

When is passive solar heating feasible?

- a) Passive solar heating is feasible if a building has a consistent solar exposure not obstructed by trees, other buildings, clouds, or other items that block the sun's rays.
- b) Positioning a structure so that its south wall has windows and an unrestricted plane will allow solar energy to enter the structure naturally.
- c) Covering the windows with an insulating material at sundown will help the structure to retain the heat.
- d) Strategically placing large water containers or building with stone or masonry where they can be warmed by the sun allows them to act as storage units that collect and hold the sun's heat.

F. *Other Activities*

If possible, have a local HVAC contractor speak to the class.

G. *Conclusion*

Heating, cooling, and ventilation are important factors to consider when building an agricultural structure. Insulating structures creates a slower heat transfer rate. Many different materials and methods of insulation are used to insulate buildings. Adequate ventilation is often imperative for a structure to function safely. Structures may also need to be heated, and several different types of heating systems may be used. The sun can be a good supplemental heat source. A well-designed building may be able to use a passive solar heating system to provide all the heat necessary.

H. *Answers to Activity Sheet*

I. *Answers to Evaluation*

1. b
2. b
3. a
4. d
5. a

6. Answers may include any two of the following: controls temperature, controls moisture levels, reduces the growth of microorganisms, diminishes odor problems, and prevents the accumulation of dangerous gases.

7. Hot water pipes or electric elements are buried just below the surface of the floor.

8. If a building has a consistent solar exposure not obstructed by trees, other buildings, clouds, or other items that block the sun's rays.

9. Insulation enhances a structure's ability to regulate temperature.

UNIT III - BUILDING CONSTRUCTION Name ______________________________

Lesson 9: Heating, Cooling, and Ventilation Date ______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. R-value indicates:

   a. Residual heat.
   b. Heat-transfer rating.
   c. Thermal units.
   d. The amount of heat available.

2. ________________ insulation comes in rolls of material in precut sections.

   a. Adhesive
   b. Batt
   c. Rigid
   d. Fill

3. Which type of insulation consists of wide rolls of material and is used for insulating metal buildings?

   a. Blanket
   b. Batt
   c. Adhesive
   d. Fill

4. Which of the following types of insulation is loose in form?

   a. Blanket
   b. Batt
   c. Rigid
   d. Fill

5. Which type of heating system will only heat objects in its path?

   a. Radiant
   b. Floor
   c. Unit
   d. Furnace

Complete the following short answer questions.

6. What are two reasons that ventilation is important?

   a.

   b.

7. What is a floor heating system?

8. When is passive solar heating feasible?

9. What is the purpose of insulation?

Lesson 9: Heading, Cooling, and Ventilation Name ____________________________

Heating, Cooling, and Ventilation Needs

Objective: Assess the heating, cooling, and ventilation needs for a farm building.

Select one of the following buildings: greenhouse, calving barn, broiler house, machinery shop, crop storage building, or any others suggested by your instructor. Prepare a short report on the heating, cooling, and ventilation needs for that building. Be sure to address the following questions.

1. What are the specific temperature requirements for this type of building?

2. Why and when will this building need to be ventilated?

3. What are the optimal temperatures for this building?

4. What are the various heating, cooling, and ventilation systems that could be used in this type of building?

5. Are there any types of heating, cooling, and ventilation systems that should not be used? Why not?

UNIT IV - CONCRETE

Lesson 1: Safety in Working with Concrete

Competency/Objective: Discuss safety in working with concrete.

Study Questions

1. **What is concrete?**
2. **How can concrete be dangerous to people?**
3. **What is the proper personal protective clothing to use when working with concrete?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit IV.
2. Activity Sheet
    a) AS 1.1: Concrete Safety

UNIT IV - CONCRETE

Lesson 1: Safety in Working with Concrete

TEACHING PROCEDURES

A. ***Introduction***

Concrete is a durable, versatile material of choice for many applications in agricultural structures. However, working with concrete does require some safety measures. Understanding and taking advantage of the suggestions provided in the lesson will help to ensure safety while working with concrete.

B. ***Motivation***

Discuss how common concrete is used in construction. Ask if anyone knows of any injuries associated with concrete. If so, have them explain the injury. If not, tell the students that a few specific hazards will be outlined in this lesson.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Ask students to explain what concrete is. Discuss the characteristics of concrete.

   What is concrete?

   a) Concrete is an artificial stone-like material consisting chiefly of sand, gravel, cement, and water.
   b) These materials are mixed together and harden and set due to a process called hydration, in which the cement combines with water and bonds to the different components.
   c) It is a versatile construction material that can be adapted to almost any application and molded into many different shapes.
   d) Concrete has a relatively low maintenance cost, is easily repaired and poured, and is easy to work.

2. Discuss the following information on the possible hazards of construction with concrete.

   How can concrete be dangerous to people?

   a) Tripping and falling over rebar and wire
   b) Working with different kinds of potentially dangerous equipment
   c) Chemical burns from concrete
      1) Perhaps the most common injury
      2) Consist of ulcerated areas where skin and flesh have been eroded away
      3) Caused by prolonged skin contact with some of the ingredients used to make cement; exposure of one hour or more will usually cause significant skin damage
      4) Prevent injury by using protective clothing and gear and immediately flushing with water and washing an exposed area
   d) Airborne powdered cement getting in the eyes or being inhaled, producing the same caustic results as exposure to wet cement

3. Discuss protective clothing and gear with students. Show the class samples of as many of these items as possible. Hand out AS 1.1.

What is the proper personal protective clothing to use when working with concrete?

a) Protective eye gear, either goggles, which provide the best protection, or safety glasses, when working with cement in wet or powdered form
b) Disposable face masks to reduce the amount inhaled when working with powdered cement
c) Long-sleeved shirt
d) Heavy work pants
e) Waterproof or heavy work gloves; waterproof gloves are preferable
f) Rubber boots

F. *Other Activities*

Ask your local EMS service, hospital, or nursing school if they would be willing to have someone come and talk to the class about concrete burns.

G. *Conclusion*

The hazards of working with concrete are greatly minimized by staying alert and using protective clothing or gear. In most cases, avoiding a problem is the best way to deal with it.

H. *Answers to Activity Sheet*

I. *Answers to Evaluation*

1. a
2. c
3. To reduce the amount inhaled when working with powdered cement
4. Immediately flushing with water and washing an exposed area
5. One hour or more
6. An ulcerated area where skin and flesh have been eroded away
7. An artificial stone-like material consisting chiefly of sand, gravel, cement, and water

UNIT IV - CONCRETE

Lesson 1: Safety in Working with Concrete

Name____________________________

Date____________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Eye protection is recommended:

   a. When working with wet or powdered cement.
   b. When working with wet cement.
   c. For exposure to cement in powdered form.
   d. For non-professionals working with wet cement.

2. What is the most common type of injury when working with concrete?

   a. Injuries from tripping and falling over rebar and wire
   b. Injuries from working with equipment
   c. Burns caused by the chemicals in wet concrete
   d. Reactions from getting powdered concrete in the eyes

Complete the following short answer questions.

3. Why should disposable face masks be worn?

4. In addition to wearing personal protective clothing, what can be done to protect against injuries from concrete burns?

5. While the length of time before damage occurs may vary, how much exposure to wet concrete usually causes significant skin damage?

6. What does a concrete burn look like?

7. What is concrete?

Lesson 1: Safety in Working with Concrete

Name ____________________________

Concrete Safety

Objective: Observe concrete safety practices in use at a construction site.

Travel to a local construction site where concrete is being poured. Observe their activities, recording in the areas listed below the proper safety practices being used, as well as any others you think are appropriate. Also, record any improvements that could be made. Be prepared to discuss what you observed after returning to the classroom.

Clothing

Eye protection

Skin protection

How concrete is moved/handled

Ventilation requirements

Teamwork/working together

UNIT IV - CONCRETE

Lesson 2: Factors Affecting the Quality of Fresh Concrete

Competency/Objective: Identify factors that affect the quality of fresh concrete.

Study Questions

1. **What are the raw materials of concrete?**
2. **What are the different mixes of concrete and their uses?**
3. **What are the different concrete additives and their uses?**
4. **What is a slump test, and why is it important?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit IV.
2. Transparency Master
   a) TM 2.1: Slump Test
3. Activity Sheet
   a) AS 2.1: Mixing Concrete

UNIT IV - CONCRETE

Lesson 2: Factors Affecting the Quality of Fresh Concrete

TEACHING PROCEDURES

A. *Review*

The agricultural industry utilizes concrete as a construction material in many different applications. As discussed in Lesson 1, being able to work with concrete safely is important because it is so common. Lesson 2 will describe important factors that influence the quality of concrete. These factors include the raw materials used, the types of mixes, concrete additives, and the importance of slump tests in pouring quality concrete.

B. *Motivation*

1. Show students examples of concrete construction around the agriculture facility. Ask them to determine if the final product is an example of quality concrete. If the example does not appear to be of good quality, ask the students why the concrete shows faults. Then ask the students if they think different types of concrete are used for different applications.

2. Ask if any of the students have ever poured concrete. For those answering yes, ask them to list the ingredients of the concrete and to explain how they were mixed. Then ask the students what the consistency and color of the concrete mixture resembled.

C. *Assignment*

D. *Supervised Study*

E. *Discussion*

1. For the finished concrete to have the proper strength and finish, the correct ingredients must be mixed together. Ask students what materials are found in a concrete mix. List the ingredients on the board or a transparency. What does each ingredient add to the mixture?

What are the raw materials of concrete?

a) Aggregates (sand and gravel)
    1) Makes up 60 to 80 percent of the volume of the concrete mixture
    2) Classified into two main categories
        (a) Fine aggregates are those particles that are smaller than a quarter inch in size.
            (1) Typically called sand
            (2) Should be clean and relatively dry
        (b) Coarse aggregates are particles larger than one quarter inch in size.
            (1) Called gravel
            (2) Should be clean and uniform in size
    3) Functions of aggregates
        (a) They provide a cheap filler material.
        (b) They are stable materials that resist forces on the concrete.
        (c) They help to maintain the volume of concrete while it sets and hardens.
    4) Can use other compounds for specialty applications
        (a) Vermiculite and pearlite are used in lightweight concrete that can be sawed.
        (b) Clay, shale, and crushed brick act as insulation.

      - (c) Steel or iron shot may be used for high density concrete for radiation shielding, as in a nuclear reactor or in the walls surrounding an x-ray laboratory.

- b) Water
  - 1) Purposes
    - (a) Water allows the concrete to be molded or shaped.
    - (b) It aids in mixing.
    - (c) Water plays an important role in hydration, the chemical reaction between water and cement that bonds the mixture together.
  - 2) Should be clean
    - (a) Water generally can be used if it is potable, or drinkable.
    - (b) It should have less than 2,000 ppm of total dissolved solids.
  - 3) Abram's Law
    - (a) This rule describes the relationship between water and concrete.
    - (b) "For given materials and conditions of handling, the strength of concrete is determined primarily by the ratio of the weight of mixing water to the weight of cement as long as the mixture is plastic and workable."
    - (c) Less water is generally better in mixing concrete, as long as the mixture is workable.
- c) Cement
  - 1) With water, forms the glue that holds concrete together
  - 2) Portland cement - most common cement used today; first patented in 1824 by Joseph Aspdin
  - 3) Steps in manufacturing portland cement
    - (a) Limestone, the base material, is taken from a quarry and crushed into a fine powder.
    - (b) The powdered limestone is then mixed with clay or shale and ground again.
    - (c) This mixture is then sent to a kiln to dry; the dried product is clinker.
    - (d) Gypsum is then added, and the mixture is ground a final time to form portland cement.
  - 4) Five types of portland cement
    - (a) Type I is for normal applications.
    - (b) Type II is used where heat buildup is a concern.
    - (c) Type III, or high early strength cement, is used where the concrete needs strength in the first two to three days after pouring.
    - (d) Type IV, or low heat cement, reduces the heat generated by hydration.
    - (e) Type V, sulfate resistant cement, is poured over alkaline soils.
  - 5) Regulated by two agencies that determine the requirements for the different categories of portland cement and work to maintain concrete quality
    - (a) American Society for Testing and Materials (ASTM)
    - (b) Canadian Standards Association (CSA)
- d) Air
  - 1) Air entraining - trapping small pockets of air in the concrete
  - 2) Benefits of air entraining
    - (a) Air-entraining improves concrete's workability.
    - (b) It improves watertightness.
    - (c) It improves finish qualities.
    - (d) It increases the concrete's resistance to freezing and thawing.
    - (e) It increases concrete's resistance to salt and sulfates.

2. Just as concrete has many applications, it may consist of many different mixes. What is being built affects the mixture of ingredients in the concrete. Discuss the different mixes. Have students complete AS 2.1.

NOTE: Several weights are important when calculating a concrete mixture. A review of common weight conversions may be helpful to fully understand the calculations needed for the mixture.

What are the different mixes of concrete and their uses?

- a) The first method of describing concrete mixes refers to the number of bags of cement in each yard of concrete, which is equal to 27 cubic feet of volume.
    - 1) Ready-mix concrete ordered through a supplier is usually ordered using this method.
    - 2) Three common ready mixes are used.
        - (a) Five bags of cement/yard; used for foundation walls and footings
        - (b) Six bags of cement/yard; used for house floors, dairy floors, driveways, and septic tanks
        - (c) Seven bags of cement/yard; used for concrete under severe conditions and concrete exposed to acids or severe weather
- b) A second method of referring to concrete mixes uses a ratio that shows the relative amounts of the different components of the concrete.
    - 1) A common mixture is 1:2:3:6, which is one part cement, two parts sand, three parts gravel, and six parts water.
    - 2) Each part consists of a particular volume, such as one cubic foot.
- c) The third method used to describe concrete mixes indicates the gallons of water mixed with each sack of cement.
    - 1) Common mixes described in this manner are 5.0, 6.0, and 7.0, which correspond in their uses to the various ready-mixes already discussed.
        - (a) Five gallons of water/sack of cement; used for concrete under severe conditions and concrete exposed to acids or severe weather
        - (b) Six gallons of water/sack of cement; used for house floors, dairy floors, driveways, and septic tanks
        - (c) Seven gallons of water/sack of cement; used for foundation walls and footings
    - 2) To learn the amounts of other components needed to make the cement, specific charts must be consulted to find the volume of each ingredient in a cubic yard.

3. For many applications and instances, changing the concrete that is poured or being able to pour concrete in less than ideal circumstances is desirable. Various additives can be used to change the properties of the concrete. List the different additives.

What are the different concrete additives and their uses?

- a) Also called admixtures
- b) Seven main categories
    - 1) Air entraining
        - (a) Force small air pockets in the concrete
        - (b) Air entraining - process of trapping air in the concrete
        - (c) Improves workability, watertightness, and finish
        - (d) Increases resistance to freezing and thawing
        - (e) Increases resistance to salt and sulfates
    - 2) Superplasticizers - increase the strength of the concrete by altering it to need less water to be workable
    - 3) Retarding
        - (a) Slow down the setting process
        - (b) Result in greater long-term strength
    - 4) Accelerating
        - (a) Speed up setting
        - (b) Result in more early strength
        - (c) Makes the concrete less vulnerable to temperature changes during setting
        - (d) Frequently used in cold weather to force the concrete to set more quickly
        - (e) Common additive - calcium chloride
    - 5) Mineral - increase strength
    - 6) Fibers
        - (a) Reduce the tendency of the concrete to break along seams or at the edges
        - (b) Helps to bind the concrete together.

7) Pigment
   (a) Change the color of the concrete
   (b) May be added to the whole batch of concrete or only to the final layer

4. Mixing concrete does not involve following a cookbook recipe, since some of the materials may already contain a certain moisture content, especially the sand. Ask students how they would determine whether the concrete has the proper consistency. Describe how to perform a slump test. Show the students TM 2.1.

What is a slump test, and why is it important?

a) Determines if the concrete is of the proper consistency
b) Indicates if more or less moisture is needed
c) Makes it possible to prepare a concrete mixture with the optimal combination of strength and workability
d) Procedure
   1) The slump test involves the use of a metal cone that is 12 inches tall, with a diameter of 4 inches at the top and 8 inches at the bottom, and open at both ends.
   2) The cone is placed on a flat surface with the wide end down.
   3) Prior to being filled with concrete, the cone may be moistened with oil to make cleanup easier.
   4) The cone is filled one-third full with concrete.
   5) The concrete is tamped down with a 12-inch metal rod 25 times to make it settle and remove any air pockets.
   6) Concrete is added until the cone is two-thirds full, and the concrete is tamped again.
   7) The cone is filled, and the concrete is tamped for the third time.
   8) The cone is carefully removed, and the concrete "slumps," or drops in height due to gravity.
   9) A straight edge is placed across the top of the cone, and a measurement is taken from the straight edge down to the average level of the top of the concrete.
   10) In most instances, the slump should be between 1 and 3 inches.
   11) Too much slump indicates too much water, while not enough slump indicates a lack of water.
   12) If too much water is present, adding aggregates or cement will thicken the mixture.
      (a) Adding ingredients should be the last resort in mixing concrete because it will result in weaker concrete.
      (b) Most state or federal construction contracts prohibit adding ingredients after the initial mix.

F. *Other Activities*

1. Using concrete mixing charts, prepare several trial mixtures and perform slump tests.

2. Visit the local ready-mix concrete plant to observe the mixing of different types of concrete.

G. *Conclusion*

Concrete has many applications. How concrete is mixed depends upon the final use of the concrete. Good concrete does not result from a random mixing of ingredients. It involves using the right raw materials in the proper proportions and any necessary additives to get the desired quality of concrete.

H. *Answers to Activity Sheet*

AS 2.1

1. 545 lbs./yd. × 11.74 yds. = 6,398 pounds
2. 1,140 lbs./yd. × 11.74 yds. = 13,384 pounds

3. 1,800 lbs./yd. × 11.74 yds. = 21,132 pounds
4. 300 lbs./yd. × 11.74 yds. = 3,522 pounds
5. 3,522 lbs. ÷ 8.3 lbs./gal. = 424 gallons

I. ***Answers to Evaluation***

1. a
2. d
3. a
4. c
5. b

6. 1 part cement, 2 parts sand, 3 parts gravel, 6 parts water

7. Aggregates, cement, water

8. To determine if the concrete is of the proper consistency and indicate if more or less moisture is needed

9. Calcium chloride

10. Answers may include any four of the following: air entraining additives, superplasticizers, retarding additives, accelerating additives, mineral additives, fibers, and pigments.

Name ______________________________

Lesson 2: Factors Affecting the Quality of Fresh Concrete

Date ______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. The type of portland cement that should be used for normal applications is:

   a. Type I.
   b. Type II.
   c. Type III.
   d. Type IV.

2. Aggregates compose ____________ percent of the total volume of concrete.

   a. 10 to 30
   b. 20 to 40
   c. 40 to 60
   d. 60 to 80

3. In making portland cement, what is the name of the mixture before the gypsum is added?

   a. Clinker
   b. Paste
   c. Concrete
   d. Masonry

4. Air entraining improves concrete's:

   a. Color.
   b. Texture.
   c. Workability.
   d. Flexibility.

5. An acceptable slump on general use concrete would be __________ inches.

   a. 0
   b. 1-3
   c. 3-5
   d. 5-7

Complete the following short answer questions.

6. What do the numbers mean in a 1:2:3-6 concrete mixture?

7. What are the three main ingredients used in concrete?

   a.

   b.

   c.

8. Why is it necessary to perform a slump test?

9. What additive is commonly used to allow concrete to be poured in cold weather?

10. What are four of the common types of concrete additives, or admixtures?

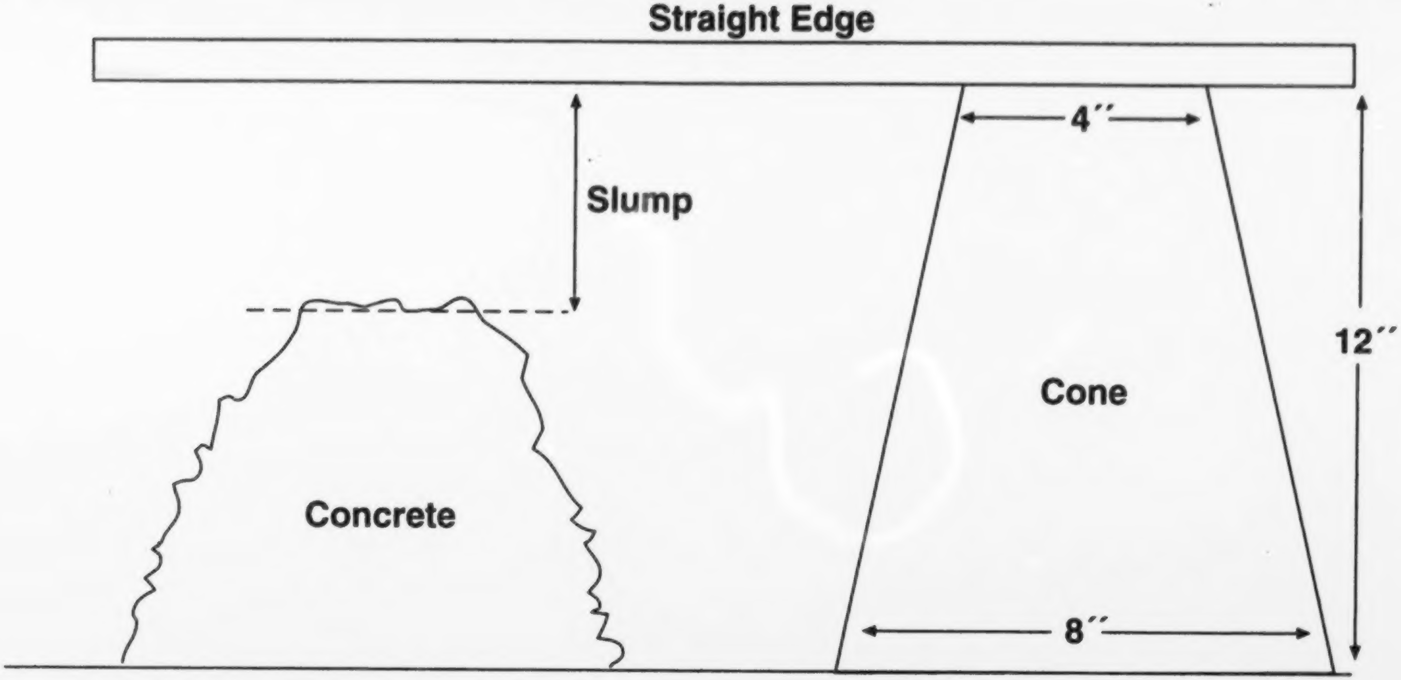
    a.

    b.

    c.

    d.

Slump Test


Straight Edge
Slump
Concrete
4″
Cone
12″
8″

Agricultural Structures, IV-19

Lesson 2: Factors Affecting the Quality of Fresh Concrete Name ____________________

Mixing Concrete

Objective: Calculate the volume of ingredients required for a specific concrete job.

Perform the necessary calculations to figure out the volume of the raw materials needed for the concrete slab described in the problem.

Assume you are going to pour a slab that will require 11.74 cubic yards of concrete. The concrete will include ¾" aggregate, fine dry sand, and air-entrained cement. You will use a mixture of .55 gallons of water per pound. Looking at a chart, you discover that you need:

Pounds of cement per cubic yard	545
Pounds of sand per cubic yard	1,140
Pounds of gravel per cubic yard	1,800
Pounds of water per cubic yard	300

Figure the total amount of materials needed for the concrete slab. (Round to the nearest pound or gallon.)

1. Total pounds of cement __________

2. Total pounds of sand __________

3. Total pounds of gravel __________

4. Total pounds of water __________

5. Gallons of water (8.3 lbs./gal.) __________

UNIT IV - CONCRETE

Lesson 3: Site Preparation

***Competency/Objective*:** Identify site preparation requirements.

Study Questions

1. **What are factors in preparing a subgrade?**
2. **What are footings, and why are they needed?**
3. **How is the foundation of an agricultural structure laid out?**
4. **What are factors in preparing the final grade?**
5. **What tools are needed for site preparation?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, Unit IV, 1999.
2. Transparency Masters
    a) TM 3.1: Footing
    b) TM 3.2: Equal and Unequal Diagonals
    c) TM 3.3: Batter Boards
3. Activity Sheets
    a) AS 3.1: Site Preparation
    b) AS 3.2: Laying Out a Building

UNIT IV - CONCRETE

Lesson 3: Site Preparation

TEACHING PROCEDURES

A. ***Review***

Lesson 2 described the components of concrete and some of the factors that affect the quality of fresh concrete. To use concrete at a specific site, various steps must be taken to prepare the site for pouring concrete. Lesson 3 will discuss the various factors that influence site preparation.

B. ***Motivation***

Locate pictures of the Leaning Tower of Pisa, and show them to the students. Ask the students why the structure is leaning and what could have been done to prevent it.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Subgrade preparation can be a detailed process due to the conditions of the site. The considerations discussed in the previous question can affect the factors in preparing a subgrade. Ask the students to think about factors that should be considered when choosing a location and how they might affect the preparation of the subgrade. Have students complete AS 3.1.

What are factors in preparing a subgrade?

a) Drainage - If the construction site does not drain well, installing a drainage system below the site may be necessary.
b) Removal of topsoil
    1) In some cases, the topsoil is scraped off the site with a tractor and blade prior to other excavation.
    2) The topsoil may be saved for later use, especially for landscaping the property, or sold.
c) Removal of organic material
    1) Organic material is matter produced by plants and animals that is found in or on the soil.
    2) The organic material on the building site needs to be removed as much as possible.
        (a) Organic material does not readily mix with concrete and can even have a slightly oily surface, which further prevents mixing.
        (b) The particles in the concrete cause inclusions, or holes created when the matter eventually decays, that weaken the overall strength of the concrete.
        (c) Organic material will keep the ground from being packed tightly to support the weight of the structure, and as the material decays, settling will occur.
    3) Organic material is typically removed with a tractor and blade.
d) Removal of rocks and stones
    1) Larger rocks and stones should be removed, since they may cause major differences in the slope of the land.
    2) They can be removed using a tractor and blade.
    3) These rocks can be placed in lower areas, as well as areas with poor drainage.
e) Subgrade slope
    1) The site should be graded using a tractor and blade to create a desired slope for drainage.

    2) A 3 percent slope away from the building is considered minimal.
- f) Packing or compacting
    1) Driving a tractor back and forth across the site so that the tires form a pattern across the previous tire tracks will pack the soil down.
    2) Portable, hand-operated packers are also available.
    3) Packing is commonly done using a sheep foot roller.
    4) Packing prevents differential settling of the soil.
- g) Sand or aggregate fill
    1) Most construction sites use fill consisting of added sand or aggregates to create a level site and leave a more uniform surface under the concrete foundation.
    2) If the soil texture and structure do not permit proper soil drainage, placing 4 to 6 inches of sand or aggregate on the site will enhance drainage by allowing water to flow downward more readily.
    3) If fill is added, the site should be packed again after the fill is in place.
- h) Vapor retarder and insulation
    1) If a drainage system cannot be used or if excessive soil moisture is a continual problem, a vapor barrier or retarder should be used under the concrete.
    2) The vapor barrier, typically polyethylene sheeting, prevents moisture from being absorbed into the concrete.
    3) In cold climates, insulation is also commonly placed under the concrete to maintain heat in the building and keep the floor warmer.
- i) Dampening the site
    1) If a vapor barrier is not used and the ground is dry, the site should be sprayed with water to dampen the fill.
    2) This practice will prevent excessively dry fill from pulling water out of the concrete during the curing process.

2. Ask students what the lowest part of a building is called. How are footings prepared? Show the class TM 3.1.

What are footings, and why are they needed?

- a) Footings are large supporting blocks of concrete between the foundation and the soil that are placed around the exterior edge of the building and under walls that will support the structure's weight.
- b) They spread the weight of the building across a larger area and make the structure more stable.
- c) Footings are necessary for several different reasons, including temperature, moisture, and soil structure.
    1) Temperature
        - (a) The frost line is the deepest point in the soil where frost is normally found during the winter.
        - (b) Footings located below the frost line will decrease or eliminate movement of the building due to expansion and contraction of the soil because of temperature changes.
        - (c) To place the footings below the frost line, the building site must be excavated to the proper depth.
    2) Moisture
        - (a) Variable levels of moisture during the year will cause the soil to expand and contract.
        - (b) The building can be stabilized by placing large footings on a sand or aggregate base.
    3) Soil structure
        - (a) Soils with a very loose soil structure tend to allow more settling of the building over time, which can be diminished by integrating larger than normal footings.
        - (b) Certain clay soils expand and contract dramatically when wet; placing footings on a layer of sand and aggregate can reduce the movement of the building.

3. Ask students how they would determine where to place the footings. Discuss how the foundation of a structure is laid out. TM 3.2 can be used to demonstrate diagonals, and TM 3.3 shows batter boards. Have students complete AS 3.2.

How is the foundation of an agricultural structure laid out?

a) The first step in laying out a building is driving stakes into the ground where the corners of the structure are to be located.
    1) For an addition to an existing building, place the two corner stakes in relation to the building by measuring the desired distance from the building and the distance between the stakes.
    2) For a new structure, drive a stake to mark the location of a corner and make measurements to the adjacent corners; after stakes are placed at these corners, make measurements from them to determine the placement of the final stake.
    3) After all the corner stakes are in place, strong twine or rope is tied between them to represent the sides of the building.
b) To determine if the stakes are square on all four corners of the building, diagonal measurements should be made from the corner stakes.
    1) When the measurements are identical, the building is square.
    2) If the building's diagonals are not equal, the stakes must be carefully moved until the diagonal measurements are identical.
    3) Because of the twine connecting the stakes, the building's dimensions remain correct.
c) The procedure for marking the corners so the stakes can be removed involves the use of batter boards.
    1) Batter boards are typically either 1" × 4" or 1" × 6" boards nailed to three 2" × 4" stakes at least four feet from the corner of the building.
    2) If the twine connecting the stakes is extended to the batter boards, the corner stakes can be removed because the intersection of the strings still marks the location of the corner of the building.
    3) Suspending a weight like a plumb bob from where the strings intersect at the corners will ensure that the strings cross exactly at the corner of the building.
    4) After the lines are in place, the position of the lines is marked, and a saw kerf about ¼ deep is sawn into the board to indicate the proper placement.
    5) When the position of the lines is marked, the stakes can be safely removed.

4. Ask students to explain how to prepare the final grade.

What are factors in preparing the final grade?

a) Slope
    1) The final slope of the building site can greatly influence the amount of concrete needed and the degree to which the forms will need to be leveled.
    2) To determine the slope of the building site, several different methods can be used.
        (a) Hand-held level
        (b) Tripod-mounted transit or level, for increased accuracy
b) Fill
    1) Fill needs to be added across the site to maintain the desired slope.
    2) Fill is especially important if major depressions or high spots are found on the building site.
    3) Low wet spots can be filled with aggregate or rocks.

5. Specific tools are used for all jobs, and site preparation for pouring concrete is no different. Although the tools are not specialized or complex, they are necessary for site preparation. Have students list tools needed.

What tools are needed for site preparation?

a) Tractor with a blade
b) Compactor or packer
c) Shovel
d) Transit or surveyor's level with tripod and surveying rod

F. *Other Activities*

1. Have students prepare the subgrade for a concrete project like a sidewalk or a building, such as a new greenhouse.

2. Using resources from the local assessor or county zoning commission, discuss the zoning regulations of different areas around the community. Discuss any zoning regulations that might apply to the areas around where students live and what measures need to be considered for construction in that zone.

G. *Conclusion*

Taking the time to plan and prepare the construction site will make the rest of the building project run more smoothly and efficiently. Subgrade preparation is crucial to the construction process, since all the following steps and procedures rely upon the quality of the subgrade.

H. *Answers to Activity Sheets*

AS 3.1

Answers will vary.

AS 3.2

1. The building will not be square unless the stakes are set at 90 degree angles.
2. Two tape measures are needed to measure the four diagonals and to place the four corner stakes.
3. The building will be crooked.

I. *Answers to Evaluation*

1. b
2. a
3. c
4. To mark the corners of a building so stakes can be removed
5. For drainage
6. Temperature, moisture, and soil structure

7. The particles of organic matter in the concrete cause inclusions that weaken the overall strength of the concrete.

8. Answers may include any three of the following: tractor with a blade, compactor or packer, shovel, and transit or surveyor's level with tripod and surveying rod.

UNIT IV - CONCRETE

Name ____________________________

Lesson 3: Site Preparation

Date ____________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. The large support blocks under the foundation of a structure are the:
    a. Bases
    b. Footings
    c. Sills
    d. Underlayments
2. The layer of polyethylene sheeting over the subgrade is called a:
    a. Vapor barrier
    b. Sub-seal
    c. Floor wrap
    d. Soil seal
3. Which of the following factors should be focused on when preparing the final grade?
    a. Removal of rocks and stones
    b. Subsurface water
    c. Slope
    d. Removal of topsoil

Complete the following short answer questions.

4. Why are batter boards used?

5. Why is subgrade slope important?

6. What are three reasons that footings need to be used?
    a.
    b.
    c.

7. Why is organic material removed from a site?

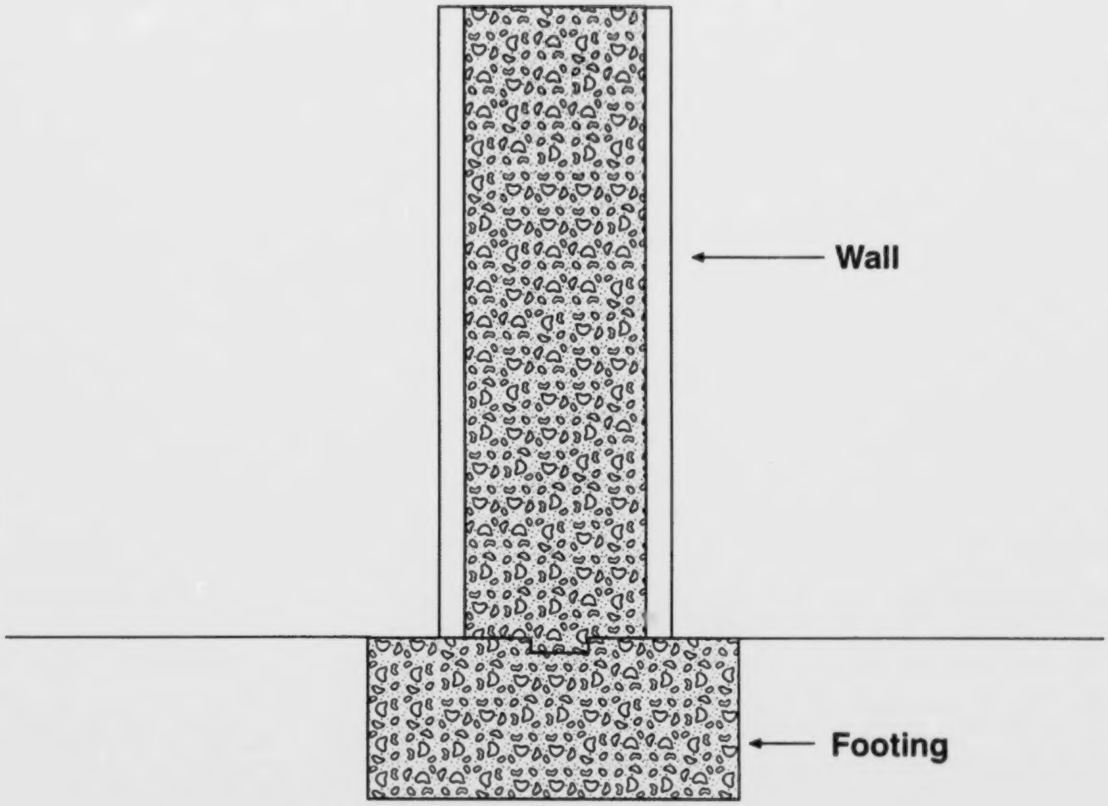
8. What are three tools used in site preparation?

   a.

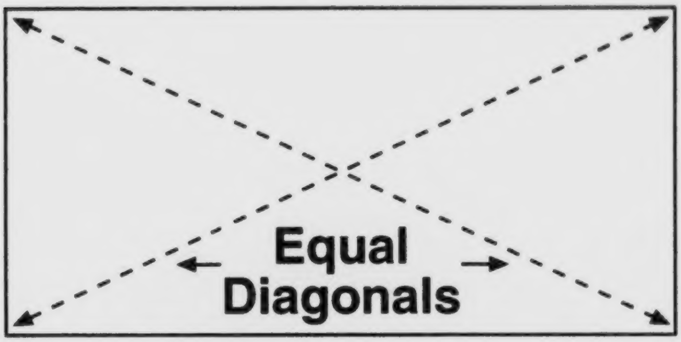
   b.

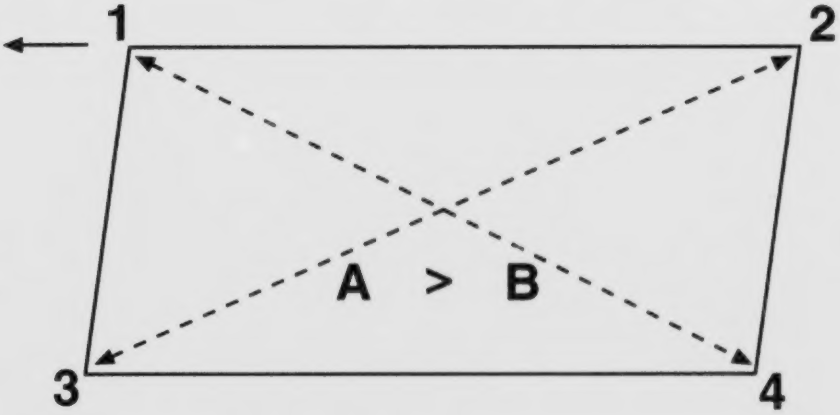
   c.

Footing

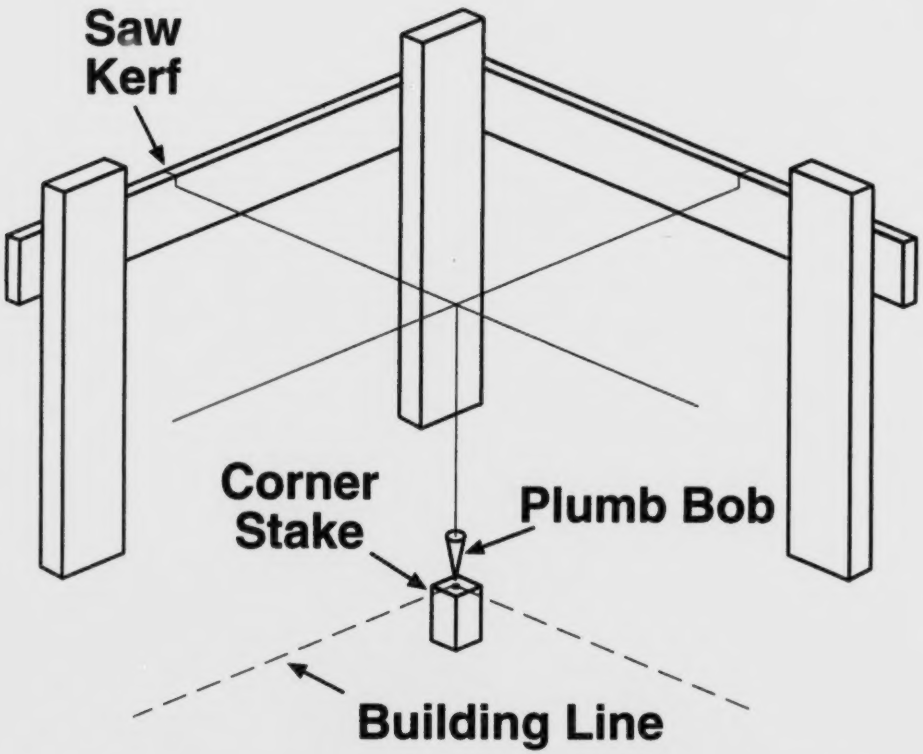

Wall
Footing

Equal and Unequal Diagonals


Equal
Diagonals



Batter Boards


Saw Kerf
Corner Stake
Plumb Bob
Building Line

Lesson 3: Site Preparation

Name ____________________________

Subgrade Preparation

Objective: Explain factors that are important in the preparation of a subgrade.

Using a sample plot of land identified by your instructor, determine what work needs to be done to prepare the subgrade for construction. Based on the factors listed below, describe the steps needed to prepare the land for the type of building suggested by your instructor.

Factor/Category	Preparation
1. Drainage	
2. Removal of topsoil	
3. Removal of organic material	
4. Removal of rocks and stones	
5. Subgrade slope	
6. Packing/Compacting	
7. Sand or aggregate fill	
8. Vapor retarder/insulation	

8. Vapor retarder/insulation

9. Dampening the site

10. Removal of rocks

11. Fill

12. Frost level

13. Soil texture/structure

Lesson 3: Site Preparation Name ______________________________

Laying Out a Building

Objective: Lay out the corner stakes of an 8' × 10' building.

Materials and Equipment:

4 stakes
2 tape measures
Twine

Procedure:

1. On a spot away from other groups of students, place the first stake for a corner of your building.
2. Using the tape measure to determine the correct distance, place the second stake 8 feet away from the first stake.
3. Measuring from the first stake along a line forming a 90 degree angle to the other two stakes, place a stake 10 feet away from the first stake.
4. Using the two tape measures, measure from the second and third stakes and place the fourth corner stake the correct distance from them.
5. Join the stakes with twine.
6. Using one of the tape measures, measure both the diagonals from opposite corners. Record your measurements below.

   Diagonal 1: __________
   Diagonal 2: __________

7. If the two diagonals are equal, the building is perfectly square. If the two diagonals are not square, move the stakes.
8. Once the four stakes are in place, measure the diagonals again and record your answers above in Trial 2.

   Diagonal 1: __________
   Diagonal 2: __________

9. If the diagonals are not square, repeat steps 6 and 7 until the diagonals are equal.

Key Questions:

1. If the stakes are placed at the correct distance apart, why is the building not necessarily square?

2. Why are two tape measures needed to perform this activity?

3. If one diagonal measurement is longer than the other, how will the difference affect the later construction of the building?

UNIT IV - CONCRETE

Lesson 4: Pouring a Concrete Slab

***Competency/Objectives*:** Describe the procedure for preparing to pour a concrete slab.

Study Questions

1. **What tools are needed for pouring concrete?**
2. **What are forms for concrete pouring?**
3. **How are forms constructed for slabs?**
4. **What is the purpose of reinforcement in concrete?**
5. **What are the types of reinforcement for concrete?**
6. **How should reinforcement be installed?**
7. **What are expansion and control joints, and when are they needed?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, Unit IV, 1999.
2. Activity Sheet
    a) AS 4.1: Reinforcing Concrete

UNIT IV - CONCRETE

Lesson 4: Pouring a Concrete Slab

TEACHING PROCEDURES

A. ***Review***

Lesson 3 discussed the various factors that influence site selection and preparation. One of the most common tasks involving concrete is pouring a slab, like that found in sidewalks and driveways. This lesson will explore the equipment, procedures, and materials used in pouring a concrete slab.

B. ***Motivation***

1. Ask students if any of them have poured concrete. If so, what was the concrete used for? Ask the class if concrete poured in a slab will always be formed and constructed in the same manner.

2. Examine the concrete in the floor of the agricultural facility and the sidewalks outside the facility. Look for any cracks or breaks. Ask the students to determine what may have caused the faults in the concrete.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Ask the students to list the tools and equipment needed to pour concrete.

   What tools are needed for pouring concrete?

   a) Sledge and claw hammers
   b) Carpenter's level
   c) Shovel
   d) Hose and water source
   e) Tape measure
   f) Transit or surveyor's level with surveying tripod and surveyor's rod
   g) Calculator
   h) Circular saw
   i) Carpenter's or framing square
   j) Lumber
   k) 16d duplex-head nails

2. Once the equipment has been obtained, construction of the forms can begin. Ask the students to explain what forms are in relation to concrete. What is the purpose of concrete forms? Discuss the different types of forms used.

   What are forms for concrete pouring?

   a) Forms are structures designed to hold the concrete in proper shape and location until it sets and hardens.
   b) Forms can be constructed of different materials.
      1) Wood forms
         (a) Wood forms for pouring a sidewalk or slab are usually made of 2" × 4" or 2" × 6" boards.

        - (b) If plywood is used, SP plywood, or plyform, should be utilized; it is a special plywood made with a waterproof glue that repels the moisture in the concrete so the concrete will not be dried out by the forms.
        - (c) Hardboard is sometimes used when forming curves because of its strength and flexibility.
        - (d) Wood forms are typically less expensive and easier to construct.
    - 2) Aluminum or metal alloy forms
        - (a) Aluminum or metal alloy forms will give a smoother, more uniform finish to the concrete.
        - (b) They are structurally stronger than wood forms.
        - (c) They will yield extremely straight, square concrete, since the forms do not bend or sway like wood forms will.
        - (d) Aluminum or metal alloy forms are easy to construct and relatively inexpensive
    - 3) Earthen forms
        - (a) Earthen forms can be constructed by shoveling soil in a pile in the desired location.
        - (b) The earth is covered with a plastic lining to prevent soil from mixing with the concrete and to keep moisture from bleeding out of the concrete into the soil.
        - (c) Earthen forms are rarely used and result in a poor quality slab.

3. Ask students how they would construct wooden forms. How are the forms braced?

How are forms constructed for slabs?

- a) Determine the desired height of the forms.
    - 1) If a 4-inch slab is to be poured, 2" × 4" boards are used, but if the board has been planed or smoothed, the end product is only 1½" × 3½".
    - 2) This board size can be used for forming a 4-inch slab if soil has been placed on the outside of the form to strengthen it and close the opening at the bottom.
    - 3) If thicker slabs are desirable, wider boards, such as 6-inch or 8-inch boards, are required.
- b) Using the strings placed in laying out the corner stakes of the slab, put the edge of the boards directly underneath the string.
    - 1) Small stakes should be driven at least 6 inches into the ground with a hammer every 4 feet along the outside of the boards.
    - 2) The top of the stakes must be below the edge of the form to allow the slab to be worked as the concrete dries.
    - 3) The stakes are nailed to the boards using duplex-head nails attached on the outside of the forms.
- c) Double check the forms to see if they are square by measuring the diagonals with a tape measure; if they are not, the forms should be adjusted.
- d) Once the forms are square, determine if the forms are level by using the transit or level, tripod, and rod.
    - 1) If they are not level, the hammer can be used on the higher spots of the form to decrease its height.
    - 2) At this point, whether the slab should slope or be level should be considered.
        - (a) If water or manure drainage is a concern, the slab should have at least a 4 percent slope in the direction that the excess water or manure should run off.
        - (b) This slope should be figured into the final placement of the forms.
- e) If the slab is to curve, plywood can be used in place of boards to make the forms.
    - 1) The plywood should be cut so the grain of the plywood runs vertically, because the stress from the concrete would crack or break the form if the grain ran horizontally.
    - 2) The stakes should be placed only 1 to 2 feet apart on curves instead of every 4 feet.

f) Forms should be secured tightly at the corners to prevent them from separating; sometimes they are attached using bolts or screws.

4. Often concrete by itself is not strong enough to handle the stress of the forces acting on it. Discuss the purposes of reinforcement. Ask students to list examples of concrete slabs that would be under great stress.

What is the purpose of reinforcement in concrete?

a) Reinforcement can strengthen the concrete and help it to resist the forces acting on it.
    1) Concrete has great compressive strength, which is the strength to resist forces pressing downward on the concrete.
    2) Concrete does not have good tensile strength, which is the ability to withstand tension or pull.
    3) Reinforcing the concrete will increase its tensile strength, especially at the edge of the slab.

b) Reinforcement will also reduce the tendency of the concrete to crack due to changes in temperature.

5. Have students list materials they think would work as reinforcement in concrete. Discuss the methods of reinforcing concrete.

What are the types of reinforcement for concrete?

a) The most common types of reinforcement are made of steel.
b) Steel has high tensile strength, which helps resist the forces acting on the concrete.
c) The steel used in concrete for reinforcement must be clean and free of rust and organic debris like leaves.
d) In some cases, specially manufactured fibers can be added to the concrete as reinforcement in place of structural steel.
e) Steel rods are also commonly known as reinforcing bars, or rebar.
    1) Can be purchased in a variety of sizes, from ¼ inch up to 2 inches in diameter
    2) Typically sold in lengths of 20 feet and cut to fit
    3) Identified by a number, like 2, 3, 4, 5, or 6, that refer to the diameter of the rod, expressed in eighths of an inch
f) The other common type of reinforcement is steel wire mesh.
    1) Consists of rods of steel wire joined in a criss-cross pattern to form a mesh
    2) Comes in a number of different diameters, ranging from 0000 (small) up to 16 gauge
    3) Differ in the spacing between the wire rods in the mesh; common spacings are 2, 3, 4, 6, 8, 10, 12, and 16 inches
    4) Sold in rolls with common widths of 36, 42, 48, and 60 inches and in common lengths of 150, 200, and 300 feet

6. Ask students how they would install the different types of reinforcement.

How should reinforcement be installed?

a) Steel reinforcement
    1) Steel reinforcement should be placed in the bottom half of the slab, where the tensile forces on the concrete are the greatest; the reinforcement is placed approximately 1 inch above the soil or fill by wiring it to 12-inch rebar stakes that have been driven into the ground.
    2) Both rods and wire mesh need to be joined where they meet.
        (a) Rebar should overlap by a length that is equal to 24 times the diameter of the rod and not less than 12 inches, while mesh should be overlapped one full square spacing plus 2 inches.

        (b) The reinforcement should be tied with thin wire where the bars or wire mesh meet.
    3) When installing steel reinforcement, be sure to place the rebar or mesh around the outside edges of the slab.
    4) The ends of the reinforcement should be placed at least 3 inches from the very edge of the slab, so that it does not eventually stick out of the edge of the concrete and pose a hazard.

b) Thickened edges
    1) Thickened edges involve placing a thicker, deeper layer of concrete at the edges of a concrete slab as a type of footing.
        (a) The edge should be 4 to 6 inches thicker than the slab itself.
        (b) The base of the thickened area should be 12 inches wide, with a 45-degree slope from the bottom of the main slab to the bottom of the thickened edge.
    2) This type of reinforcement is used on the perimeter of feeding floors and driveway edges where livestock or vehicles enter the paved area.

7. When placing larger slabs of concrete like a concrete pad or sidewalk, the slab will sometimes move. Ask students to examine the sidewalks outside the agricultural facility or school. What is the purpose of the lines in the concrete? Have students complete AS 4.1.

What are expansion and control joints, and when are they needed?

a) Expansion and control joints may either be grooves made in the concrete or material placed in the concrete to prevent breaks or control where the concrete breaks.
    1) Joints can often prevent breakage, but if the concrete does break, these devices will also limit the location and force the break to form a straight line.
    2) The straight grooves commonly seen across sidewalks and driveways are expansion and control joints.

b) Expansion and control joints can be made using several different methods.
    1) For joints consisting of grooves in the concrete, a piece of angle iron or a v-shaped piece of wood can be pushed in a straight line through the drying concrete.
    2) A mason's trowel can also be used to inscribe a groove into the drying concrete.
    3) Another method is to saw grooves in the concrete, cutting the joints into the dried concrete with a masonry saw 4 to 12 hours after the concrete is poured.
    4) An alternative method of installing expansion and control joints is to place small strips of IKO board on edge in the form before the concrete is poured.
        (a) Expansion and control joints should always be placed in straight lines perpendicular to each other.
        (b) For slabs 4 inches thick or less, joints should be made in the concrete every 10 feet; for slabs 6 inches thick, joints should be included every 15 feet.

F. *Other Activities*

Have the students form and pour a sidewalk or small concrete slab at the agricultural facility or school. Be sure to include reinforcement and control joints.

G. *Conclusion*

One of the most common tasks when working with concrete is pouring a slab. This lesson outlined the tools used in pouring a concrete slab, the procedure for laying out and forming concrete slabs, the methods of reinforcing concrete, and the use of expansion and control joints. Through careful attention to the procedures described, a concrete slab can be placed with minimal concrete defects.

H. *Answers to Activity Sheets*

AS 4.1

1. Answers will vary.

2. Answers will vary.
3. Sidewalks and edges of driveways, etc.

I. *Answers to Evaluation*

1. b
2. d
3. a
4. b

5. Rods and wire mesh

6. Rebar should overlap by a length that is equal to 24 times the diameter of the rod and not less than 12 inches, while mesh should be overlapped one full square spacing plus 2 inches. Both should be tied together with thin wire.

7. Expansion and control joints may either be grooves made in the concrete or material placed in the concrete to prevent or control where the concrete breaks.

8. Answers may include any three of the following: sledge and claw hammers, carpenter's level, shovel, hose and water source, tape measure, transit or surveyor's level with a surveying tripod and surveyor's rod, calculator, circular saw, carpenter's or framing square, lumber, and 16d duplex-head nails.

9. Reinforcement can increase the tensile strength of concrete and help it to resist the forces acting on it; it will also reduce the tendency of the concrete to crack due to changes in temperature.

10. Determining the desired height of the forms

UNIT IV - CONCRETE

Lesson 4: Pouring a Concrete Slab

Name ____________________________

Date ____________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. The plywood used for concrete forms should:

   a. Be a special color.
   b. Be made with waterproof glue.
   c. Have lots of knots.
   d. Have a special type of grain.

2. Aluminum or alloy forms are ______________________ than wood.

   a. Easier to build
   b. Poorer in quality
   c. Weaker
   d. More expensive

3. Earthen forms should be lined with:

   a. Plastic.
   b. Clay.
   c. Organic material.
   d. Oil.

4. What is the minimal amount of slope on a slab for drainage?

   a. 3 percent
   b. 4 percent
   c. 8 percent
   d. 15 percent

Complete the following short answer questions.

5. What are the two most common steel reinforcement materials used in concrete?

   a.

   b.

6. How should reinforcement materials be overlapped during installation?

7. What are expansion and control joints?

8. What are three tools needed for pouring concrete?

   a.

   b.

   c.

9. What are two purposes of reinforcement?

   a.

   b.

10. What is the first step in constructing wooden forms?

Lesson 4: Pouring a Concrete Slab

Name ______________________

Reinforcing Concrete

Objective: Compare the strength of reinforced and non-reinforced concrete.

Materials and Equipment:

1 8-foot 1" × 6" board
20 16d duplex-head nails
⅛" welding wire
Wax paper or plastic wrap
Latex gloves
Eye protection
Concrete mix

Procedure:

NOTE: Safety glasses and gloves should be worn whenever working with concrete to protect your eyes from splashing concrete and your skin from chemical burns from the reaction of the cement and water.

1. Construct two forms from the materials provided. The forms should have inside measurements of 2" × 3" × 24". The forms will basically be open-topped boxes into which the concrete will be poured.

2. Line the forms with wax paper or plastic wrap to prevent the concrete from sticking to the wood in the forms.

3. In one of the forms, place two pieces of rebar 3/4 of an inch from the bottom. Do not place rebar in the second box. Support the rebar with small supports made from welding or other stiff wire. These supports are made in the shape of a capital letter M, with the rebar resting in the valley on top of the M.

4. Pour concrete into both of the boxes. Be sure to not displace the rebar.

5. As the concrete is drying, write your name in the concrete in both forms. This will identify your samples and indicate which side of the concrete was up when it was poured.

6. Allow the concrete to cure for seven days.

7. After seven days, remove the forms and place the concrete on top of two sturdy supports with your name facing upwards.

8. Using a large hammer, strike both beams of concrete as close to the middle as possible.

Key Questions:

1. What happened to each of the samples when they were struck with a hammer?

2. What effect did the rebar have on the strength of the concrete?

3. What are two examples of locations where additional strength would be needed for concrete?

   a.

   b.

UNIT IV- CONCRETE

Lesson 5: Ordering, Pouring, and Finishing Concrete

Competency/Objective: Explain the procedure for ordering, pouring, and finishing concrete.

Study Questions

1. **How is the necessary quantity of concrete calculated?**
2. **What are factors to consider when ordering concrete?**
3. **What are the procedures for pouring a slab?**
4. **What are the different types of concrete finishes and their applications?**
5. **What are the procedures for different finishes?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, Unit IV, 1999.
2. Job Sheet
   a) JS 5.1: Pouring a Concrete Curb

UNIT IV - CONCRETE

Lesson 5: Ordering, Pouring, and Finishing Concrete

TEACHING PROCEDURES

A. ***Review***

Lesson 4 discussed the procedures for constructing forms and reinforcing a concrete slab. This lesson will examine the calculations needed for ordering concrete, the procedures for pouring and finishing concrete slabs, and the different types of finishes that can be used.

B. ***Motivation***

Ask students to compare the differences between the concrete in sidewalks around the school and the concrete that forms the floor of the laboratory. Why are the two concrete slabs different?

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. When large quantities of concrete are needed, people often order the concrete from a ready-mix business. Ask students how they would order the concrete for a slab the size of the classroom.

   How is the necessary quantity of concrete calculated?

   a) Concrete is ordered in cubic yards.
   b) One cubic yard is equal to 27 cubic feet.
   c) For a rectangular slab, multiply the length, width, and depth in feet of the slab, and divide this number by 27.

   $$\text{Length (ft.)} \times \text{Width (ft.)} \times \text{Depth (ft.)} \times \frac{\text{yd.}^3}{27\ \text{ft.}^3} = \text{Cubic yards of concrete}$$

   d) If the slab to be poured is circular, the formula for the volume of a circle is used to calculate the amount of concrete needed.

   $$\pi\ (3.14) \times \text{Radius}^2\ (\text{ft.}^2) \times \text{Depth (ft.)} \times \frac{\text{yd.}^3}{27\ \text{ft.}^3} = \text{Cubic yards of concrete}$$

   e) When ordering concrete, the amount ordered will usually be more than the amount calculated by a factor of 10 to 25 percent.
      1) Multiply the amount needed by 1.1 or 1.25 to provide the extra concrete.
      2) The additional material will make up for any spilled concrete and differences in soil or fill level, especially for low spots.

2. When deciding to order concrete, a number of issues should be addressed. Ask the students if the same type of concrete would be ordered for all situations. What other factors should be considered when placing an order for concrete?

   What are factors to consider when ordering concrete?

   a) Weather

        1) Concrete should preferably not be poured in a rain storm or when temperatures are below 40 degrees or above 85 degrees.
        2) These weather conditions will affect the rate of curing, or hardening, of the concrete as well as the overall final strength of the concrete.
        3) Calcium chloride has to be added to the mix for pouring concrete in cold weather.
    b) Conditions affecting the type of cement needed - The concrete mix may include different types of Portland cement, depending on factors such as whether the concrete is to be poured on alkaline soils or in areas where heat may build up, whether the concrete needs strength in the first two to three days, or whether the heat generated by the concrete needs to be reduced.
    c) Labor needs and availability - The arrival of the delivery truck should be timed to occur when sufficient labor will be available.
    d) Access to the area by truck
        1) Most ready-mix businesses offer trucks with extension slides to allow the concrete to be poured over greater distances and avoid hauling the concrete in wheelbarrows.
        2) Companies generally also have a few trucks that can pump the concrete to a location higher than the tires of the truck.
    e) Water needs
        1) The site needs to be sprayed with water if the fill is dry.
        2) The concrete is sprinkled with water as it cures to increase the moisture content and improve the strength of the finished concrete.
        3) Water will be used to clean equipment.

3. After the concrete has been ordered and delivered, it is time to pour the concrete. Ask the students what procedure they would follow in pouring a slab.

    What are the procedures for pouring a slab?

    a) The site needs to be moistened while the concrete is being delivered or mixed on site.
    b) The concrete should be poured as soon as possible after its arrival at the site or after being mixed.
        1) Maximizes the amount of moisture in the concrete, increasing its strength
        2) Aids in maintaining the proper slump
    c) An important point to remember is that concrete will begin to set 30 to 60 minutes after pouring.
        1) Results in reduced strength if the concrete is moved in any way during the first hour after pouring
        2) Should move the truck or mixer as close as possible to the final location of the concrete to avoid having to move it in wheelbarrows
    d) The chute, or discharge tube, should be placed as close to the ground as possible when unloading the concrete; if the chute is too high, the impact will partially separate the aggregate from the cement mixture.
    e) As the concrete fills the forms, a shovel or spade should be pushed through it, especially at the edges.
        1) Will mix the aggregate well and move it away from the edge somewhat, resulting in a smoother finish at the edges
        2) Removes any air bubbles that may have resulted from pouring, giving the concrete more strength
    f) If the slab to be poured is wider than 10 feet, pouring the slab in two or more sections should be considered because slabs wider than 10 feet will be more difficult to finish.

4. The surface of the concrete can be worked to create finishes with several different textures. Ask the students to describe the different finishes they have seen and where they were used. Why was that particular type of surface chosen for that area?

What are the different types of concrete finishes and their applications?

a) Smooth - used where ease of cleaning is desired, as for floors in a shop, house, or grain bin
b) Rough - for traction on sidewalks, livestock walkways, inclined walks, and steps
c) Aggregate - consists of exposed rocks on the surface of the concrete; used for traction and decorative purposes anywhere a decorative surface is desired, such as sidewalks

5. The processes for creating each of these different types of finishes are somewhat different. However, they all must be done carefully to produce the desired surface. Have students describe the process they would follow for each of the finishes. Have students complete JS 5.1.

What are the procedures for the different finishes?

a) Smooth
    1) Screed the concrete.
        (a) Screeding the concrete involves moving a board across the concrete along the top of the forms.
        (b) This process will move concrete into lower spots inside the form and remove excess concrete.
        (c) Screeding is typically done by moving a straight 2" × 4" board back and forth at a 90-degree angle to the edge of the form.
    2) Use a bull float to work the aggregate below the surface.
        (a) A bull float is a wide board or flat piece of aluminum that is held level with the surface and tipped up slightly along the front edge as it moves across the concrete.
        (b) The float will force the aggregate below the surface, leaving the concrete relatively smooth.
    3) Remove the ridges left by the bull float using a power trowel, steel hand trowel, or magnesium hand float.
        (a) If the person pouring the concrete has access to a power trowel, it should be used; the power trowel works in a circular pattern to smooth away any edges, leaving a very smooth surface overall.
        (b) If a power trowel is not available, a steel hand trowel can be used to achieve the same effect.
        (c) The hand trowel or magnesium float should be worked in curving motions, with the front edge sloped slightly upward to help compact the surface.
    4) An edger should be used along the forms as the concrete begins to set to separate it from the forms and leave a slightly rounded edge.
    5) At the same time, control or expansion joints should be applied if they are needed.
b) Rough
    1) Screed the surface.
    2) Use a bull float to force the aggregate down.
    3) Remove the ridges using a power trowel or hand trowel.
    4) Pull a push broom across the surface of the curing concrete to leave small, even grooves in the concrete that will reduce slippage and increase traction, especially if water freezes on the surface.
    5) An edger is used along the forms.
    6) Expansion and control joints are then applied.
c) Exposed aggregate
    1) Screed the concrete.
    2) Work it with a bull float.
    3) Lightly work the concrete with a power or hand trowel, with less concern for creating a smooth surface.
    4) To add the aggregate to the finish, evenly apply a layer consisting only of aggregate over the surface.

    - (a) This layer of aggregate is embedded using a board similar to the screed to force the aggregate into the concrete to a depth of about one half of its diameter.
    - (b) The aggregate should not be forced too far into the concrete, because the desired finish will be reduced
5) Allow the concrete to dry until surface water disappears.
6) After the water has evaporated and the mixture can support a person's weight, use a hose and bristle broom to remove any film of concrete on the surface of the exposed aggregate.

F. *Other Activities*

Tour a local ready-mix facility to learn the steps involved in mixing, delivering, and pouring concrete.

G. *Conclusion*

Ordering the concrete required for a specific job is the first step in preparing to pour a concrete slab. Once the concrete arrives, it is carefully poured and finished to meet the needs of the construction project. If the procedures described in this lesson are followed, the slab poured will consist of high quality, lasting concrete.

H. *Answers to Activity Sheet*

I. *Answers to Evaluation*

1. a
2. c
3. d
4. b
5. c
6. d
7. b
8. (120 × 4 × .33) / 27 = 5.87 cubic yards
9. 5.87 × 1.1 = 6.46 cubic yards

10. Answers may include any three of the following: weather, conditions affecting the type of cement needed, labor needs and availability, access to the area by truck, and water needs.

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Name______________________________

Lesson 5: Ordering, Pouring, and Finishing Concrete
Date______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. The process of leveling the concrete with the top of the forms is called:

   a. Screeding.
   b. Floating.
   c. Finishing.
   d. Smoothing.

2. What is the preferred maximum width of forms for a slab?

   a. None
   b. 5 feet
   c. 10 feet
   d. 15 feet

3. The type of concrete finish where the rocks are exposed is called:

   a. Smooth.
   b. Rough.
   c. Hard.
   d. Aggregate.

4. The concrete finish that should be used on ramps leading into livestock barns is:

   a. Smooth.
   b. Rough.
   c. Rocky.
   d. Aggregate.

5. Which tool is used to work the aggregate below the surface of the concrete during finishing?

   a. Trowel
   b. Screed
   c. Bull float
   d. Shovels

6. Which tool would be used for the final step on a smooth finish?

   a. Bull float
   b. Darby
   c. Screed
   d. Magnesium hand float

7. Control joints can be made in newly formed concrete:

   a. Immediately after the concrete is poured.
   b. At the end of the finishing process.
   c. Between screeding and floating.
   d. At any time.

Complete the following short answer questions.

8. How much concrete would be needed for a sidewalk that is 120 feet long, 4 feet wide, and 4 inches thick?

9. Overestimating the amount needed for question 8 by 10 percent, how much concrete should be ordered?

10. What are three factors that are important to consider when ordering concrete?

    a.

    b.

    c.

Lesson 5: Ordering, Pouring, and Finishing Concrete

Name____________________________

Pouring a Concrete Curb

Objective: Pour concrete to make a curb.

Materials and Equipment:

Wood and duplex nails for forms
Tape measure
Concrete
2 1" pipes, 1' long
Wire
Rebar
Wire for rebar supports
Shovel or spade
Oil
Hand trowel
Board for screed
Latex gloves
Eye protection

Procedure:

1. The purpose of this exercise is to build curbs like those found in a parking lot. Since the size of concrete curbs varies, measurements should be taken of the curbs already in place to duplicate their size.

2. Construct a form using the materials provided by your instructor. Build the form so that the curb is upside down, leaving a larger opening for pouring the concrete. Be sure to use duplex nails so the form can be removed more easily after the concrete has set.

3. Once the form is finished, insert rebar reinforcement into it using wire supports to hold it in place. Since the form is upside down, the rebar will now be at the top of the form.

4. Approximately two feet from each end of the form, insert an oil-covered pipe vertically into the form. The pipes will be removed after the concrete has set, leaving anchor holes through the curb. Support the pipe with wire wrapped around the form.

5. If the concrete is being mixed by the class, mix the concrete. If the concrete is being ordered, the next step depends on the arrival of the truck.

6. When the concrete is ready, begin pouring the concrete into the forms. Pour until the form is filled halfway and then use a spade or shovel to work up and down through the concrete, especially around the edges. This will remove air bubbles and move the aggregate away from the edges, creating a smoother finish.

7. Pour the concrete to the top of the form. Using a spade or shovel, work the concrete that was added to the form to remove air pockets.

8. Using a straight board as a screed, work the top until the entire surface is level and even.

9. Allow the concrete to begin to set.

10. Once the surface of the concrete starts to dry and no water is standing on top of the poured concrete, take a small hand trowel and smooth the surface of the curb.

11. Allow the curb to cure for at least three to four days or preferably up to one week for maximum strength. If the curing is done outside, sprinkle water on the surface of the concrete once or twice a day for the first two to three days.

12. After the concrete has set completely, remove the pipes and turn the form over to remove the curb. If necessary, remove the ends of the form to separate the curb from the form.

UNIT IV - CONCRETE

Lesson 6: Curing Concrete

Competency/Objective: Identify factors affecting the quality of cured concrete.

Study Questions

1. **What is the process of concrete curing?**
2. **Why is curing important?**
3. **What are the methods of curing concrete?**
4. **What are the different types of concrete defects?**
5. **When and how should forms be removed?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit IV.
2. Activity Sheet
    a) AS 6.1: Curing Concrete

UNIT IV - CONCRETE

Lesson 6: Curing Concrete

TEACHING PROCEDURES

A. ***Review***

Lesson 5 discussed the processes of pouring and finishing concrete. Perhaps the most important stage in working with concrete is the actual curing of the concrete. This lesson will explore the process of curing and the causes of common defects in concrete.

B. ***Motivation***

Ask students to explain how concrete hardens. One common answer will be that the concrete dries out as water evaporates. If they give this answer, have students explain why the concrete remains in a particular shape after drying and does not crumble away into the dry ingredients.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. After the concrete is poured into the molds and finished, the concrete needs to harden. Ask the students why the concrete hardens.

What is the process of concrete curing?

a) Curing is the hardening of concrete.
b) Curing is the result of hydration, which is the mixing of a compound with water.
c) The curing process involves a chemical reaction between water and the elements in Portland cement.
d) As the cement starts to react with the water, a substance called a gel is formed from the chemicals in the cement and water.
e) Eventually the gel becomes a solid mass, thickening and hardening the concrete.
f) The rate of curing for pure concrete without additives is affected by temperature.
    1) Between 65 and 75 degrees Fahrenheit - ideal temperatures for curing
    2) Higher than 75 degrees - will cause the concrete to cure too quickly
    3) Between 32 and 65 degrees Fahrenheit - concrete will cure, but more slowly
    4) Below 32 degrees - will not cure
g) The length of time that pure concrete is allowed to cure depends on the outside temperature.
    1) Above 70 degrees Fahrenheit - at least five days
    2) 50 to 70 degrees Fahrenheit - at least seven days
    3) Less than 50 degrees Fahrenheit - at least seven to ten days and preferably longer
    4) Ideal curing time - 28 days

2. Ask students what would happen if the concrete did not cure completely. What effect would it have on the concrete?

Why is curing important?

a) Causes the concrete to harden and determines its strength
    1) To a point, the more water the concrete can retain, the greater its strength will be.

2) For maximum strength, the concrete must have adequate water to continue the chemical reaction until it has completely hardened.
b) Gives concrete the ability to hold water in or out

3. Have the students list conditions that might affect curing concrete. What changes may be made to the curing process to counteract these conditions? Hand out AS 6.1.

What are the methods of curing concrete?

a) Cold weather curing
1) Do not pour concrete onto frozen soil, because the ground will cause the water in the concrete to freeze; heat the ground using propane torches.
2) When pouring concrete in temperatures below 50 degrees Fahrenheit, heat the concrete so that it is between 60 and 80 degrees Fahrenheit by heating the water added to the mixture.
3) Provide protection for the forms in order to retain the heat.
(a) Consists of straw, plastic, or paper spread directly on the surface of the concrete
(b) Should remain over the concrete for at least 48 hours, and preferably for four to five days
4) Another option for heating the concrete is to build an enclosure around the forms and heat the entire area with fuel-burning heaters.
(a) Should be used with caution because of the carbon dioxide they give off, which sometimes reacts with the concrete to form a thin layer of calcium carbonate over its surface
(b) Requires adequate ventilation for the exhaust fumes
5) Leave the forms around the concrete for as long as possible to act as insulation.
6) One way to test whether the concrete froze during curing is to pour hot water on it.
b) Hot weather curing
1) If outside temperatures are above 80 degrees Fahrenheit, more water will be needed in the concrete mixture to maintain the optimal slump of 1 to 3 inches.
2) High temperatures will also shorten the time that the concrete can be worked or finished; reduce the time needed for pouring by having plenty of labor available.
3) Hot weather can cause incomplete curing due to the rapid curing of the outside layer of the concrete.
4) Several methods can be used to keep the concrete cool.
(a) Adding cold water
(b) Dampening the subgrade
(c) Placing wet burlap over the concrete
(d) Lightly spraying cold water on the concrete
c) Moist curing
1) Retaining the moisture on the surface of the concrete is called moist curing.
2) Moist curing can be accomplished using a variety of methods.
(a) Placing moist burlap sacks over the surface of the concrete
(b) Spraying the surface with water
(c) Covering it with waterproof paper
(d) Covering the surface with plastic sheets
(e) Spraying the concrete with a curing compound, which places a chemical membrane over the concrete to seal in the moisture

4. After curing, different types of defects may become apparent. Ask students to describe concrete defects that they have seen. Discuss the sources of various types of faults.

What are the different types of concrete defects?

a) Honeycomb surface

    1) Results from the use of a concrete mixture that was too dry and needed more water to mix completely
    2) Causes air pockets around the unmixed dry materials, resulting in a honeycomb structure
    3) Prevention
        (a) Moist enough mix
        (b) Spading the edges of the forms to avoid dry spots
- b) Air pocket
    1) A hole left in the concrete after curing due to the presence of a confined body of air
    2) Prevention
        (a) Spading the edge of the forms
        (b) Wiping oil on the surface of the forms
- c) Rock pocket or gravel streak - caused by cracks or knotholes in the forms that allow the mortar to flow out, leaving pockets and veins of coarse aggregate
- d) Sand streaking
    1) Involves small ribbons of sand running across the surface of the concrete
    2) Caused by a mixture that was too wet, which allows the coarse aggregates to sink and separate out from the rest of the mixture, leaving the fine aggregate to work to the top
- e) Red to pink stain
    1) The result of the resin in the plywood forms reacting with the concrete
    2) Will generally happen with forms used for the first time and will diminish with continued use
    3) Can be reduced by using older forms
    4) Difficult to remove but will fade and disappear in time
- f) Rust stain
    1) Caused by steel reinforcement that has worked to the edge or surface of the concrete
    2) Can be cleaned from the concrete using a chemical solution of diluted oxalic acid but will reappear as long as the exposed metal is present
- g) Dusting
    1) The appearance of a powdery material on the surface of newly hardened concrete
    2) Causes
        (a) Excess clay or silt in the concrete
        (b) Premature floating and troweling
        (c) Addition of carbon dioxide from heating systems
        (d) Condensation of water on the surface before floating and troweling have been completed
        (e) Dry-heat heaters that lower the humidity too quickly and cause incomplete curing
        (f) Inadequate or no curing due to insufficient water in the mixture
- h) Scaling
    1) Occurs when the surface of hardened concrete slabs breaks away to a depth of 1/16 to 3/16 of an inch
    2) Causes
        (a) Freezing and thawing of newly placed concrete
        (b) Freezing and thawing of concrete that is not air-entrained
        (c) Application of deicing salts on concrete that is not air-entrained
        (d) Faulty workmanship caused by finishing the concrete while it was still "bleeding" or giving off water
- i) Crazing
    1) The presence of numerous fine hairline cracks in the surface of a newly hardened slab due to shrinkage
    2) Causes
        (a) Rapid surface drying by the sun or wind
        (b) Premature floating and troweling on a moist surface along with the rapid loss of moisture

(c) Overuse of tools such as a power screed or bull float, which works too much mortar to the surface of the concrete

5. After the concrete has cured, it is time to remove the forms. Ask students to describe how and when the forms should be removed.

When and how should forms be removed?

a) Remove the forms when the concrete has cured sufficiently to support its own weight.
   1) In summer or warm weather conditions - two days after pouring
   2) In winter or cold weather conditions - at least four to seven days
   3) Can be removed in less time if accelerating additives are used; can cut the curing time in half
b) Any reinforcement around the forms should be loosened prior to their removal, including all the duplex nails holding the forms together.
c) If the forms were properly coated with oil, they should come away easily, without the use of force.
d) The forms should then be cleaned to remove any concrete residue before storing them away for future use.
e) The slab can be cleaned with water once the forms have been removed.

F. *Other Activities*

Observe the concrete around the school. Have students look for defects. Discuss what could have been done to avoid these problems.

G. *Conclusion*

Concrete curing is caused by the reaction of water and cement; it allows the concrete to harden and gain strength. The process of curing concrete may vary depending on weather and temperature conditions. When the concrete is cured to the point that it can support its own weight, the forms may be removed. Various types of defects may become apparent after curing if the concrete was not mixed or worked properly.

H. *Answers to Activity Sheet*

1. The concrete cured at room temperature should be the strongest for each test. The other environments are too wet, too cold, too hot, or too dry.
2. The concrete should get stronger as the length of time increases.
3. Concrete should be cured at room temperature and for longer periods of time, up to 28 days.

I. *Answers to Evaluation*

1. d
2. d
3. a
4. c
5. c
6. d

7. Answers may include any three of the following: excess clay or silt in the concrete, premature floating and troweling, addition of carbon dioxide from heating systems, condensation of water on the surface before floating and troweling have been completed, dry-heat heaters that lower the humidity too quickly and cause incomplete curing, and inadequate or no curing due to insufficient water in the mixture.

8. Adding cold water to the concrete mix

9. Curing is important because it causes the concrete to harden and strengthen and because it gives concrete the ability to hold water in or out.

10. Answers may include any two of the following: placing moist burlap sacks over the surface of the concrete, spraying the surface with water, covering it with waterproof paper, covering the surface with plastic sheets, and spraying the concrete with a curing compound, which places a chemical membrane over the concrete to seal in the moisture.

UNIT IV - CONCRETE

Lesson 6: Curing Concrete

Name ____________________________

Date ____________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. The curing process is the result of:

   a. Evaporation.
   b. Drying.
   c. Stiffening.
   d. Hydration.

2. Which defect is caused by a knothole in the form that allows the mortar to flow out?

   a. Sand streaking
   b. Crazing
   c. Honeycomb surfaces
   d. Rock pockets

3. In summer, forms can be removed ___________ days after pouring pure concrete.

   a. Two
   b. Three
   c. Four
   d. Five

4. When temperatures are below 50 degrees Fahrenheit, heat the concrete mix to:

   a. 40° to 60° F
   b. 50° to 70° F
   c. 60° to 80° F
   d. 70° to 90° F

5. What is the name of the defect that results in small cracks on the surface of newly hardened concrete?

   a. Dusting
   b. Honeycomb
   c. Crazing
   d. Scaling

6. The ideal temperature for curing pure concrete is:

   a. 50° to 60° F
   b. 55° to 65° F
   c. 60° to 70° F
   d. 65° to 75° F

Complete the following short answer questions.

7. What are three possible causes of dusting on concrete?

   a.

   b.

   c.

8. How can concrete be cooled?

9. What are two reasons that curing is important?

   a.

   b.

10. What are two ways to keep concrete moist for moist curing?

    a.

    b.

Lesson 6: Curing Concrete

Name ______________________________

Curing Concrete

Objective: Compare the strength of concrete that is cured in different environmental conditions.

Materials and Equipment:

Mixed concrete
15 3" pieces of PVC pipe, 6" long
Hydraulic press
Oil (new motor oil)
¼" steel rod, 8" long
4' x 4' piece of plywood or sheet metal
Buckets
Oven
Freezer
Sand

Procedure:

1. Cover the inside of the PVC pipes with a light coating of oil to prevent the concrete from sticking to the pipes.

2. Prior to filling the pipes with concrete, label and number them to identify the type of curing: freezer, room, water, oven, and sand. Three pieces of pipe should be used for each type of curing. For instance, the pipes to be placed in the freezer may be labeled "Freezer 1", "Freezer 2", "Freezer 3", etc.

3. Fill each of the pipes with concrete. Stand the pipes on a piece of plywood or sheet metal.

4. After filling each pipe, work the steel rod through the concrete to remove any air pockets.

5. Place the pipes in the appropriate environments: in a freezer, at room temperature in the laboratory, submerged in water, in an oven at 150 degrees Fahrenheit, and submerged in a bucket of dry sand.

6. After three days, remove the pipes labeled with the number 1 from each location.

7. Remove the cement from each pipe using a hydraulic press.

8. Once the column of cement has been removed, test its strength by placing it horizontally on the hydraulic press and forcing the press downward until it breaks. If possible, use a hydraulic press that measures the force exerted, and record the measurements.

9. Compare the six columns to determine which has the most strength.

10. After seven days, repeat the tests with concrete from the pipes labeled with a 2, and determine which has the most strength.

11. After 14 days, repeat with the process with the concrete from the last set of pipes. Determine which column of concrete has the most strength.

Key Questions:

1. Which cylinder from each test had the most strength, and why?

2. What difference did time have on the strength of concrete?

3. Considering the information from this test, how should concrete ideally be cured?

UNIT IV - CONCRETE

Lesson 7: Pouring Concrete Walls

Competency/Objective: Describe the procedure for pouring a concrete wall.

Study Questions

1. **What tools are needed for pouring walls?**
2. **What are the form types available for walls?**
3. **How are forms constructed for walls?**
4. **How should reinforcement be installed in walls?**
5. **What are the procedures for pouring a wall?**
6. **What are methods of preventing water from entering a structure?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit IV.
2. Transparency Masters
   a) TM 7.1: Plywood Forms
   b) TM 7.2: Parts of a Form
3. Job Sheet
   a) JS 7.1: Preparing Forms for a Concrete Wall

UNIT IV - CONCRETE

Lesson 7: Pouring Concrete Walls

TEACHING PROCEDURES

A. ***Review***

Lesson 6 described procedures for curing concrete. So far in this unit, the focus has been on working with concrete slabs. Lesson 7, however, describes the construction of concrete walls. In particular, the construction of forms and the procedures used for pouring a concrete wall are discussed.

B. ***Motivation***

Ask students how pouring a concrete wall would be similar to pouring a slab and how it would be different. Then ask them what problems might occur when pouring a wall that would not happen with a slab.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. When pouring a concrete wall, a number of tools are needed to do the job correctly. Have students list these tools.

What tools are needed for pouring walls?

a) Trowel
b) Steel tamp rod
c) Shovel
d) Hand level
e) Tape measure
f) Circular saw
g) Hammer

2. Several types of forms can be used to construct a wall. Discuss the different types of forms. Use TM 7.1 to illustrate plywood forms.

What are the form types available for walls?

a) Wood
    1) Most commonly used material
    2) Constructed of plywood made with an exterior glue
b) Aluminum or metal
    1) Produce straighter walls because the metal does not bend from the weight of the concrete as much as wood does
    2) More expensive than plywood forms
c) Styrofoam
    1) Made of Styrofoam with steel mesh embedded in it to add strength to the form
    2) Is not removed after the concrete is poured; becomes a permanent part of the wall
    3) Have several advantages and disadvantages
        (a) Advantages
            (1) Less labor required
            (2) Allows for construction in all types of weather

        - (3) Lightweight and snap together for easy construction
        - (4) Less bracing required
        - (5) Can run wiring and pipes through the forms easily
        - (6) Energy efficient
        - (7) Can be finished or painted with exterior paint
    - (b) Disadvantages
        - (1) Not reusable
        - (2) Much more expensive than wooden forms and slightly more expensive than the metal forms

3. Ask students how they would build forms to pour a concrete wall. TM 7.2 shows the different parts of a form. If possible, show them a sample snap tie and holder. Hand out JS 7.1.

How are forms constructed for walls?

- a) Wood forms have several parts.
    - 1) Stake
        - (a) Typically made from a 2" × 4" board
        - (b) Placed 4 feet apart or less for strength
    - 2) Brace - Nailed to the stake and the form to help keep the forms vertical
    - 3) 1" x 4" tie - Keeps the two sides of the form apart to give the wall the desired thickness
    - 4) Sheathing
        - (a) Forms the sides of the form
        - (b) Typically made of plywood
    - 5) Wale
        - (a) 2" × 4" board that prevents the wall from bulging outward from the weight of the concrete
        - (b) Nailed to the form with the wide side down
    - 6) Holder
        - (a) Holds wales and snap ties in place
        - (b) Placed over the snap ties, and then wales are placed in the holder
        - (c) Holds the entire form together
    - 7) Snap tie
        - (a) Specially constructed pieces of wire that run through the wall
        - (b) Helps hold the forms the correct width apart
        - (c) Has a wider spot that allows the holder to clamp tight on it without slippage
    - 8) Spreader
        - (a) Typically consists of a 2" × 4" board cut to a length that is equal to the thickness of the wall
        - (b) Placed inside the form to keep its sides apart while the concrete is poured
    - 9) Wire tie
        - (a) Hold the forms the correct width apart
        - (b) Used on the ends of a form
        - (c) Constructed of twisted wire
    - 10) Key - Groove made in a footing that allows the concrete from the walls to bond to the concrete in the footing
    - 11) Marker nails - Driven through the form from the outside to mark the desired height of the concrete if it will not be poured to the top of the form
- b) Start by standing the sheathing upright where the wall will be poured.
- c) The holders, snap ties, and wales should be put on to hold the two sides together.
- d) Spreaders can be added on the inside of the form.
- e) Stakes are placed in the ground about 5 to 8 feet away from the form.
- f) The braces are cut to the correct distance to reach the stakes.
- g) The form should be checked using a level to make sure it is level and plumb.
- h) The braces are nailed to the forms and the stakes to hold the forms in the correct position.
- i) The wire ties are placed on the ends of the forms

j) The 1" x 4" ties are secured to the ends of the forms with duplex-head nails.
k) The forms must be square, because if they are not the building will not be square; the diagonal method is used to check whether they are square.
l) All of the pieces on the form must fit tightly together, and the forms must be strong, so they should be checked for weak spots prior to pouring the concrete.
    1) Usually occur at corners or where two forms meet
    2) Can be braced using additional 1" x 4" ties and duplex-head nails attached diagonally across the corners, or across the joint where the forms meet
m) High quality lumber must be used in constructing forms because weak spots from cracks, knot holes, or other problems will reduce the strength of the form.

4. Once forms have been constructed, reinforcement should be added in the walls to make them stronger. Ask students how they would reinforce the walls. How should the rebar be inserted?

How should reinforcement be installed in walls?

a) Walls are typically reinforced with rebar.
b) The rebar should be placed in the middle of the wall at an equal distance from each side of the form.
c) It should not stick out the top.
d) Rods are placed length-wise through the walls, spaced 8 to 12 inches apart.
e) Rods are driven vertically in the ground every 4 feet to support the horizontal rods.
f) The vertical and horizontal rods are tied together using thin wire.

5. Once the reinforcement is in place, it is time to pour the concrete. Ask students how they would fill the forms. Where would they start? How would they level the concrete? How is a structure connected to the concrete used in a foundation?

What are the procedures for pouring a wall?

a) Before filling the forms with concrete, they should be lightly oiled to prevent the concrete from sticking.
b) The concrete is then poured from one end or corner, working along the wall, with the corner being filled before moving on.
c) Enough concrete should be poured in one spot to fill the form before moving so that the concrete does not have to be shoveled backward to fill low spots.
d) Spreaders must be removed as the form is filled.
e) When the form is filled to the desired level, the steel tamp rod is run up and down through the concrete to help work out air bubbles.
f) After each of the walls has been poured, the top surface of the concrete must be smoothed and leveled using a small trowel or a board cut the width of the wall; the tool is worked along the top of the forms in a process similar to screeding.
g) After the first wall has been leveled and smoothed and the surface starts to dry, anchor bolts can be inserted into the concrete.
    1) Standard bolts placed with the head of the bolt in the moist concrete to anchor the wooden portion of the structure
    2) At least ⅜ of an inch in diameter and typically 4½ to 5 inches long
    3) Generally set at least 2 inches into the concrete
    4) Straight when placed in the concrete
    5) Spaced 4 to 6 inches apart along each side of the building, with one bolt set in from the corner near each end of a wall; the distance between them depends on wind loads
    6) Placed where they will not interfere with the upright studs in the walls
h) Before the forms are removed, concrete walls should cure for at least one week, preferably longer.
i) When the concrete has cured enough, the forms are removed.
    1) Loosen all holders and wales

    2) Remove braces and stakes
    3) Remove sheathing
    4) Twist snap ties back and forth until they break or snap off
    5) Fill holes left in the concrete by wire ties with cement paste

6. Ask students what can be done to prevent water from entering a structure.

   What are methods of preventing water from entering a structure?

   a) Vapor barrier - specially constructed protective material attached to the inside of the underground portion of a concrete wall to eliminate condensation
   b) Waterproofing materials
      1) Painted on the outside of a wall
      2) Typically made of polyurethane, rubber, tar, or other waterproofing compounds
      3) May also consist of a layer of polyethylene plastic glued to the outside of the wall that will repel water from the soil
   c) Waterstop - synthetic material placed between concrete construction joints to stop water from entering through the joints
   d) Drainage pipes - placed around the structure to move excess water away

F. *Other Activities*

Observe a concrete wall being poured at a construction site. Discuss the construction of the forms and the techniques used when pouring the concrete.

G. *Conclusion*

Pouring concrete walls is a common task in constructing buildings, especially for houses with basements or crawl spaces. Constructing the forms correctly will make for straighter, stronger walls that will make building the structure much easier. Pouring the concrete in the forms is a relatively easy task, although it is necessary to carefully work out all air bubbles and smooth the top surface. After one week, the forms can be removed, and other construction can continue.

H. *Answers to Activity Sheet*

I. *Answers to Evaluation*

1. a
2. c
3. b
4. d
5. Wood, metal, or Styrofoam
6. To keep the concrete from sticking to the form
7. At corners or where two forms meet

8. Students should give answers similar to the following.
   a) Prevents the wall from bulging outward from the weight of the concrete
   b) Helps hold the forms the correct width apart
   c) Marks the desired height of the concrete if it will not be poured to the top of the form

9. Answers may include any two of the following: trowel, steel tamp rod, shovel, hand level, tape measure, circular saw, or hammer.

10. Standing the sheathing upright where the wall will be poured

UNIT IV - CONCRETE

Lesson 7: Pouring Concrete Walls

Name______________________________

Date______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. The protective material attached to the inside of the underground portion of a concrete wall to eliminate condensation is called:

   a. Vapor barrier.
   b. Water stop.
   c. Water repellant.
   d. Moisture barrier.

2. What connects the wooden portion of a house or building to the concrete?

   a. Metal straps
   b. Weight
   c. Anchor bolts
   d. Wood screws

3. How far apart should the rebar be placed inside the wall to reinforce it properly?

   a. 4 to 8 inches
   b. 8 to 12 inches
   c. 12 to 16 inches
   d. 16 to 20 inches

4. Concrete in walls should be allowed to cure for a minimum of:

   a. 1 day.
   b. 3 days.
   c. 5 days.
   d. 1 week.

Complete the following short answer questions.

5. What are the three main types of wall forms?

   a.

   b.

   c.

6. Why should forms be lightly oiled before the concrete is poured?

7. Where do weak spots usually occur on forms?

8. What is the purpose of each of these parts of a wall form?

   a. Wale -

   b. Snap tie -

   c. Marker nail -

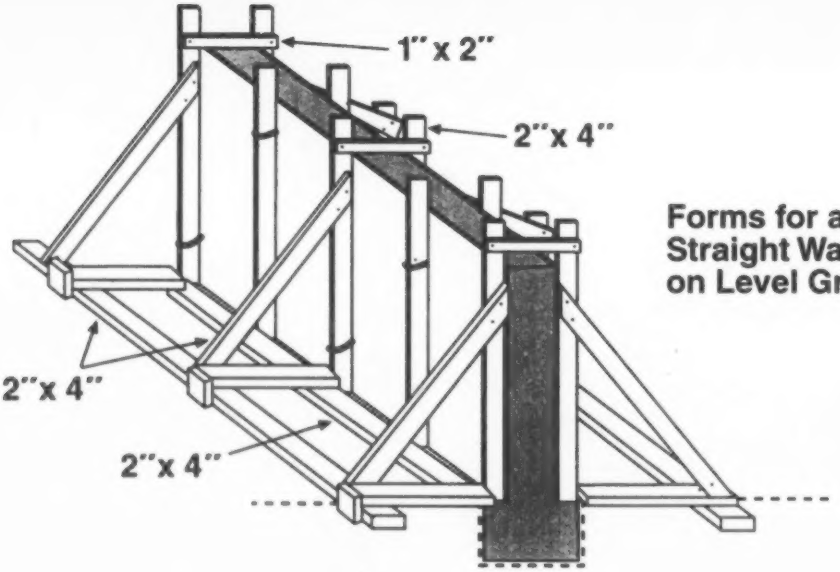
9. What are two tools needed for pouring concrete walls?

   a.

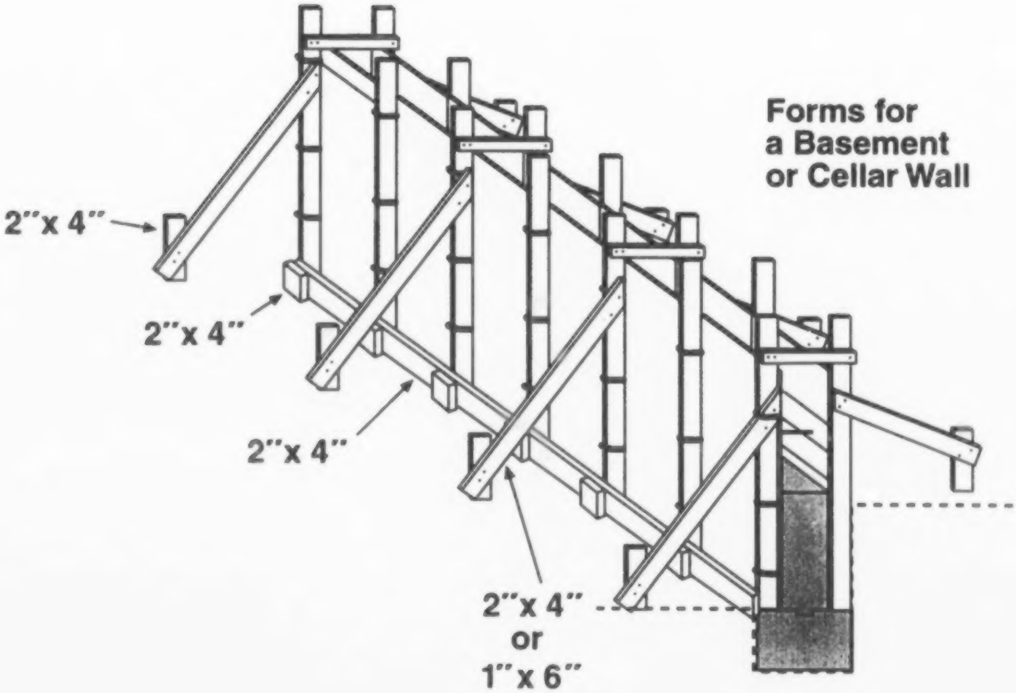
   b.

10. What is the first step in assembling forms?

Plywood Forms


1"x 2"
2"x 4"
2"x 4"
2"x 4"

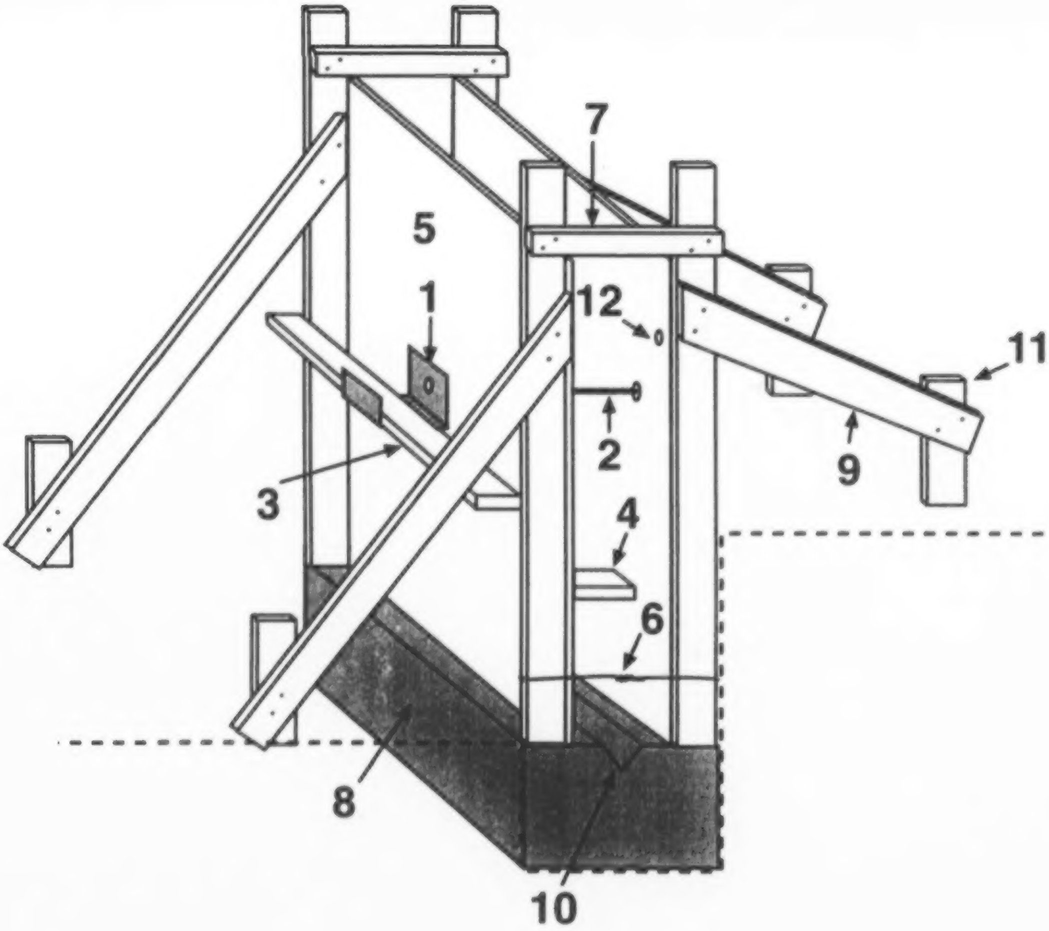
Forms for a Straight Wall on Level Ground


2"x 4"
2"x 4"
2"x 4"
2"x 4"
or
1"x 6"

Forms for a Basement or Cellar Wall

Agricultural Structures, IV-83

Parts of a Form



1. Holder
2. Tie Snap
3. Wale
4. Spreader
5. Sheathing
6. Tie Wire
7. 1´´x 4´´ Tie
8. Footing
9. Brace
10. Key
11. Stake
12. Marker Nail

Lesson 7: Pouring Concrete Walls Name______________________________

Preparing Forms for a Concrete Wall

Objective: Construct and set up the forms to pour a concrete wall.

Materials and Equipment:

Plywood
16d duplex-head nails
4 snap ties
8 snap tie holders
2 8-foot 2" × 4" boards for wales and braces
1 4-foot 1" × 4" board for ties
Wire for wire ties
2" × 4" scraps for spreaders
Electric drill and bits
Level

Procedure:

1. Using the plywood provided, cut the sheathing for the two sides of the form. The wall should be 4 feet by 4 feet.
2. Using the drill, drill holes for the snap ties in the sheathing. Drill the holes to provide maximum strength by using only four snap ties.
3. Place the snap ties through the holes, and place the holders over the ends of the snap ties.
4. Add spreaders inside the form.
5. Add wales to the outside of the form.
6. Nail the 1" × 4" ties to the end of the form.
7. After setting the forms in the location indicated by your instructor, drive stakes in the ground about 4 feet from the bottom of the form.
8. Cut four braces to run from the top and bottom of the form to the stakes at each corner.
9. Using the level to check that the forms are straight, nail the braces to the form and stakes.
10. Double check to make sure that everything fits tightly and is square.
11. If your instructor permits, as an additional challenge, construct forms in cooperation with another group to form a 90-degree corner from the two forms.

UNIT V - ELECTRICITY

Lesson 1: Electrical Safety

Competency/Objective: Identify the dangers and safety practices associated with electrical work.

Study Questions

1. **What are the basic rules of electrical safety?**
2. **What are the sources of electrical defects in equipment?**
3. **What should be done if someone gets shocked?**
4. **What are the types of circuit protection?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit V.
2. Activity Sheet
    a) AS 1.1: Electricity on the Internet

UNIT V - ELECTRICITY

Lesson 1: Electrical Safety

TEACHING PROCEDURES

A. *Introduction*

Everyone uses electricity in many different ways every day. Electricity is also a major energy source in agriculture. However, it can be dangerous if used improperly. To work with electricity safely, understanding the basic safety practices, and hazards is important. This lesson will provide information that will help you work safely with electricity.

B. *Motivation*

1. Take students on a tour around the shop or school. Point out possible electrical hazards. Make note of warning signs around electrical equipment. Discuss the importance of these warnings.
2. Bring a damaged and/or burned out electrical fixture to class. They can usually be obtained from a local electrician or electrical company. Explain the hazards of faulty wiring and the misuse of electrical equipment.

C. *Assignment*

D. *Supervised Study*

E. *Discussion*

1. Ask students what they believe to be the major hazards associated with electricity. Discuss the various aspects of electrical safety.

What are the basic rules of electrical safety?

- a) Two major safety concerns with electricity
    - 1) Shock is the passing of an electric current through the body and the body's reaction to it; it affects the rhythm of the heart,
    - 2) Electrical fires have two main causes.
        - (a) Wires overheat, generally due either to a restriction in the flow of electricity through the conductor or an overloaded system.
        - (b) An electrical current jumps a gap, creating sparks; the gap may be produced by broken wires or improper electrical connections.
- b) Precautions to minimize these hazards
    - 1) During the installation and repair of electrical systems, always disconnect the main power source before working with the system.
    - 2) Follow state and local electrical codes when installing new systems.
    - 3) Manufacturers' instructions for the installation and use of electrical equipment are another important source of information about the proper procedures to use.
- c) Sources of electrical hazards
    - 1) The use of extension cords is another factor that can create electrical hazards.
        - (a) Do not place extension cords under items, such as rugs or other things that put weight directly onto the cord.
        - (b) Avoid placing cords in high traffic areas, which can also lead to insulation damage and a restriction of electrical flow.
        - (c) Always uncoil a long extension cord before plugging it in.
        - (d) If an extension cord becomes warm or smells of burning rubber, discontinue its use immediately.

2) Fuses and breakers, safety devices designed to shut off electrical flow, can be a source of electrical hazards.
    (a) Check out the system and correct the problem before replacing a fuse or resetting a breaker.
    (b) Never use a higher capacity fuse or circuit breaker for a repair; electrical systems are designed to carry a certain load, and an attempt to increase this load will burn out the system.
3) A situation that can be extremely hazardous is performing an installation near wet areas.
    (a) While working with electrical systems or appliances in areas that are wet or damp, make sure that the power is disconnected.
    (b) Utilize cabinets, shelves, and stands to keep tools and appliances dry.
    (c) Install GFCI outlets in noncorrosive plastic device boxes in wet or damp areas.
4) As with most hazardous situations, misuse due to the human factor tends to be the single greatest cause of electrical mishaps.
    (a) Remember that safety devices put in place by manufacturers have a purpose; do not damage or disable them.
    (b) Do not use any electrical product that is damaged in any way.
    (c) Do not remove a plug from an outlet by pulling on a cord.
    (d) Never carry a power tool by its cord.
5) Joining two wires that are composed of different metals can pose an electrical hazard; a special type of connector should be used.

2. Ask students if they have ever seen or used electrical equipment that had a defect and what that defect was. Then discuss the common sources of defects.

What are the sources of electrical defects in equipment?

a) Ground wire
    1) Occurs when the ground, or neutral, wire is missing, broken, improperly connected, or not connected at all
    2) Can lead to shorts in the system and a possible shock hazard to anyone using equipment connected to the line
b) Open conduit
    1) Conduit - metal or plastic tube that encloses electrical wires
    2) Leads to wire damage from water entering the open conduit
    3) Allows for wear and deterioration of the insulation
    4) Can create a short circuit
c) Damage to insulation
    1) Occurs when the insulation becomes worn, wet, or oily
    2) Can lead to short circuits, shocks, and fire hazards
d) Damage to equipment
    1) Occurs during manufacturing or installation and use
    2) Normally occurs in switches, receptacles, and extension and appliance cords
    3) Can lead to shock and fire hazards
e) Lack of maintenance
    1) Can cause dirty, improperly adjusted electrical equipment to overheat, throw sparks, and short out
    2) Can create a fire hazard
f) Misuse through carelessness
    1) Most common source of defects
    2) May result in the misuse of equipment, improper wiring practices, limited knowledge of electrical systems, and working around electricity in wet environments without proper precautions

3. Ask students if they have ever been shocked (by either an electric fence or by electrical equipment). Discuss what it felt like. Then describe what should be done if someone receives a serious shock.

What should be done if someone gets shocked?

a) For someone receiving an electric shock of 120 to 240 volts
    1) Disconnect the source of the electric current, if possible.
    2) If it cannot be disconnected, a long pole or other item of nonconductive material, such as wood or fiberglass is needed.
    3) Insulate oneself by making sure to avoid any liquids or wet areas.
    4) Use the pole to move the person or the conductor, depending on which is easier and safer to move.
b) For a power source over 240 volts
    1) Assume that the downed wire is live and can kill.
    2) Keep everyone at least 200 feet away because the static electricity in the air can arc to individuals wearing any type of metal.
    3) Contact emergency personnel immediately.
    4) Call the power company to give them the exact location of the incident.
c) In either case
    1) Never attempt to grab a person in direct contact with a live wire.
    2) The electrical current will "freeze" muscles, thus compounding the situation and putting a rescuer at risk of electrocution and death.
d) First aid given once the victim is moved from the electrical source
    1) Check to see if the victim is conscious.
    2) Check for signs of breathing and a pulse.
    3) Perform CPR if trained.
    4) If burns are present, cover them with a dry, sterile dressing; do not attempt to cool electrical burns since efforts to soothe them may only make the situation worse and can lead to further damage.
    5) Never move the victim unless an immediate threat to his or her safety exists; due to the nature of an electrical injury, the victim may experience damage to the spine that would be worsened by being moved.

4. Ask students what they would do if they walked into a room, turned on some sort of appliance, and the power shut off. What is the likely reason the electricity shut off? Discuss the different circuit protection devices. Hand out AS 1.1.

What are the types of circuit protection?

a) Overcurrent devices
    1) Devices that limit the amperage in any wire to the maximum permitted
    2) Consist of fuses and circuit breakers
    3) Both rated by the number of amps that will travel through the overcurrent device without triggering it; the size of the wire used in the system will determine the amperage rating of the overcurrent device used
b) Fuse
    1) Short piece of metal that has been experimentally tested to melt at a predetermined flow of amps
    2) Housed in a nonconductive material for protection and removal
c) Circuit breaker
    1) Semi-permanent device positioned in the service panel during wire circuit installation
    2) Does not require replacement when a break occurs in the circuit
    3) Resembles a toggle switch with a handle
    4) Has four switch positions
        (a) On
        (b) Tripped

        (c) Off
        (d) Reset
    5) Has a mechanism inside that "trips" the breaker and disconnects the load in an overload situation
    6) Most commonly used type of overcurrent device because of the ease of resetting it
d) Ground fault circuit interrupter (GFCI) - interrupts the flow of electricity in order to prevent electrical shock if a fault exists in the circuit that will not affect a fuse or circuit breaker

F. *Other Activities*

Schedule a guest speaker from a local power company to discuss electrical safety.

G. *Conclusion*

Because electricity affects the lives of every person, electrical safety should be a concern for everyone. For people working with electricity in particular, being aware of the electrical hazards that may affect them will help enable them to work safely. They must be familiar with safety devices and know what to do if someone is injured by electricity.

H. *Answers to Activity Sheet*

I. *Answers to Evaluation*

1. b
2. c
3. d

4. Answers may include any three of the following: problems with the ground wire, open conduits, damage to insulation, damage to equipment, lack of maintenance, and misuse through carelessness.

5. Answers may include any one of the following.

    - Do not place extension cords under items, such as rugs or other things that put weight directly onto the cord.
    - Avoid placing cords in high traffic areas, which can also lead to insulation damage and a restriction of electrical flow.
    - Always uncoil a long extension cord before plugging it in.
    - If an extension cord becomes warm or smells of burning rubber, discontinue its use immediately.

6. Fuse and circuit breaker

7. Disconnect the source of the electric current, if possible. If it cannot be disconnected, a long pole or other item of nonconductive material, such as wood or fiberglass, is needed to move the person or the conductor.

UNIT V - ELECTRICITY

Lesson 1: Electrical Safety

Name ______________________________

Date _______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. The part of the body affected by electricity when a person is shocked is the:

   a. Bones.
   b. Heart.
   c. Lungs.
   d. Liver.

2. GFCI outlets should be placed in ____________________ in wet areas.

   a. Metal boxes
   b. Aluminum boxes
   c. Plastic boxes
   d. Bare walls

3. A device that limits the amperage in any wire to the maximum permitted is called a:

   a. Outlet.
   b. Limiter.
   c. Undercurrent device.
   d. Overcurrent device.

Complete the following short answer questions.

4. What are three of the six sources of electrical defects in equipment?

   a.

   b.

   c.

5. What is one thing that can be done to minimize electrical hazards with electrical extension cords?

6. What are the two types of overcurrent devices for circuit protection?

   a.

   b.

7. What is the first thing you should do if someone receives a shock of 120 to 240 volts?

Lesson 1: Electrical Safety

Name____________________________

Electricity on the Internet

Objective: Explore the various sources of information on electricity and electrical safety available on the Internet.

Using the following web sites or others approved by your instructor, investigate one web site and use the information found to answer the questions. Include a print out of the web site's home page. Then use the links from one of these sites or a search engine to find another source of electrical information.

Web Resources

National Electrical Safety Foundation	http://www.nesf.org/
National Fire Protection Association	http://roproc.nfpa.org/home.html
Electric Links	http://www.codecheck.com/

1. What is the name of the site?

2. What is its purpose (educational, marketing, regulatory, etc.)?

3. What is the internet address of this site?

4. What types of information are available on this site?

5. Who sponsors this site?

6. Who would use this site the most and why?

7. What is the most interesting thing about electricity you learned from this site?

UNIT V - ELECTRICITY

Lesson 2: Electrical Terminology

Competency/Objective: Identify the terms associated with electrical work.

Study Questions

1. **What are the terms and definitions of electricity?**
2. **What is the NEC?**
3. **How are NEC guidelines enforced?**
4. **What does a UL listing mean?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit V.
2. Activity Sheet
    a) AS 2.1: Electrical Terms

UNIT V - ELECTRICITY

Lesson 2: Electrical Terminology

TEACHING PROCEDURES

A. ***Review***

Lesson 1 addressed electrical safety, electrical defects, and types of circuit protection. To work with electricity safely, a knowledge of the basic terminology is important in order to understand it properly. The NEC and Underwriters Laboratories play an important role in electrical work as well.

B. ***Motivation***

Point out to the class that electricity has its own set of terms and definitions. Ask students if they know what volts, ohm, amps, and watts are. Discuss why it is important to understand this terminology.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. To become proficient in working with electricity, an individual needs to become familiar with the terminology used. Have students list electrical terms they have heard and discuss their definitions.

What are electrical terms and definitions?

a) Conductor - wire through which electrical current is carried through a circuit; typically made from copper, aluminum, or copper-clad aluminum
b) Circuit - complete, uninterrupted path of electricity
c) Positive, or hot, wire - wire that acts as a conductor of electrical power; typically color-coded red or black
d) Neutral wire - wire that conducts electricity from the appliance back to the source, completing the circuit; color-coded white or gray
e) Insulation - protective covering on the wires; usually made of plastic or rubber
f) Grounding - electrical connection from the piece of equipment or appliance to the earth
g) Fuse - safety device that prevents the overload of an electrical circuit by "burning out" and interrupting the electrical flow
h) Circuit breaker - automatic flip switch located on an electrical circuit that breaks, or shuts off, the current when overloaded
i) Alternating current (AC) - electrical current that alternates, or changes its direction of flow at regular intervals, usually 60 times per second
j) Direct current (DC) - electrical current that flows steadily in the one direction through a conductor; produced by a generator or battery
k) Amperage - measurement of the flow of current through an electrical system; measured in amperes, or amps (A)
l) Voltage - measurement of the pressure created by electricity moving through a conductor; measured in volts (V)
m) Wattage - measurement of the total electrical power within a system; calculated by multiplying amperage and voltage and measured in watts (W)
n) Kilowatt (kW) - 1,000 watts
o) Resistance - opposition to the flow of current as it moves through a conductor; measured in ohms
p) Voltage drop - loss of electrical pressure from the source to the point of use

e) Short circuit - wires in the same circuit come into contact, causing the flow of electrical current to move from its desired path

2. Ask students what the acronym NEC stands for. Discuss the purposes of the NEC.

What is the NEC?

a) In 1911, the National Fire Protection Association sponsored the development of the National Electrical Code (NEC).
b) The goal of the NEC is to address four issues.
  1) Changing power needs in the United States
  2) Safe user practices of new technology
  3) Minimum standards for electric wiring practices and materials used nationwide
  4) Increased energy use in the home, workplace, and community
c) Printed periodically in book form.
d) Topics covered in the 1996 edition
  1) Wiring and protection
  2) Wiring methods and materials
  3) Equipment for general use
  4) Special occupancies (buildings for particular purposes)
  5) Special equipment
  6) Special conditions
  7) Communication systems

3. Ask students if they think that they are required to follow NEC guidelines in every structure they build. Why might it be a good idea to do so?

How are NEC guidelines enforced?

a) The NEC is basically a reference and resource for state and local governments and for insurance companies.
b) Government agencies utilizing the NEC include the Occupational Safety and Health Administration (OSHA) and state and local building inspectors.
c) Insurance companies may require the use of NEC guidelines in buildings they insure, primarily for those structures being built for rental or resale.

4. Show students the UL listing on some type of electrical equipment. Ask them if they know what it means. Discuss the purpose of a UL listing. Have students complete AS 2.1.

What does a UL listing mean?

a) Underwriters Laboratories, Inc. (UL) - independent, not-for-profit testing and certification organization that evaluates products, materials, and systems in the interest of public safety
b) UL listing
  1) Means that representative samples of the product have been tested and evaluated with reference to nationally recognized safety standards for electric shock, fire, and related safety hazards
  2) Important because it provides a degree of product quality assurance

F. ***Other Activities***

Have students work in groups to list everyday items (for example, a 40-watt light bulb) or situations in which many of the terms discussed in this lesson are used.

G. ***Conclusion***

To fully understand how to work with electricity, knowing the basic terms associated with it is vitally important. The terms addressed in this lesson are fundamental to the entire industry. Understanding each of them is imperative to learning how electricity works and how to wire circuits.

H. ***Answers to Activity Sheet***

1. Conductor
2. Circuit breaker
3. Wire that acts as a conductor of electrical power; typically color-coded red or black
4. Voltage
5. Covering on the wires; usually made of plastic or rubber
6. Neutral wire
7. Fuse
8. Complete, uninterrupted path of electricity
9. Alternating current (AC)
10. National Electrical Code (NEC)
11. Measurement of the flow of current through an electrical system; measured in amperes, or amps
12. Electrical connection from the piece of equipment or appliance to the earth
13. Short circuit
14. Measurement of the total electrical power within a system; calculated by multiplying amperage and voltage and measured in watts
15. Underwriters Laboratories, Inc. (UL)
16. Loss of electrical pressure from the source to the point of use
17. 1,000 watts
18. Direct current (DC)
19. Opposition to the flow of current as it moves through a conductor; measured in ohms
20. UL listing

I. ***Answers to Evaluation***

1. c
2. e
3. f
4. a
5. g
6. d
7. b

8. Answers may include any one of the following.

   - Changing power needs in the United States
   - Safe user practices of new technology
   - Minimum standards for electric wiring practices and materials used nationwide
   - Increased energy use in the home, workplace, and community

9. A UL listing means that representative samples of the product have been tested and evaluated with reference to nationally recognized safety standards for electric shock, fire, and related safety hazards.

10. Government agencies, including the Occupational Safety and Health Administration (OSHA) and state and local building inspectors, and insurance companies

UNIT V - ELECTRICITY

Lesson 2: Electrical Terminology

Name ____________________________

Date ____________________________

EVALUATION

Match the term on the right with the description on the left.

1. ______ Electrical current flowing steadily in the same direction through a conductor
2. ______ The loss of electrical pressure from the source to the point of use
3. ______ The opposition to flow of current as it moves through the conductor; measured in ohms
4. ______ A unit of measurement for the flow of current through an electrical circuit
5. ______ The actual wire through which electricity is carried through a circuit
6. ______ Electrical current that changes its direction of flow at regular intervals
7. ______ Amperage multiplied by voltage

a. Ampere
b. Wattage
c. Direct current
d. Alternating current
e. Voltage drop
f. Resistance
g. Conductor

Complete the following short answer questions.

8. What is one of the four issues addressed by the National Electrical Code?

9. What does a UL listing mean?

10. Who enforces NEC guidelines?

UNIT V - ELECTRICITY AS 2.1

Lesson 2: Electrical Terminology Name ____________________

Electrical Terms

Objective: Define important terms used in the electrical industry.

Fill in the term or the definition for each of the blanks below.

	Term	Definition
1.	____________	Wire through which electrical current is carried through a circuit; typically made from copper, aluminum, or copper-clad aluminum
2.	____________	Automatic flip switch located on an electrical circuit that breaks, or shuts off, the current when overloaded
3.	Positive, or hot, wire	
4.	____________	Measurement of the pressure created by electricity moving through a conductor
5.	Insulation	
6.	____________	Wire that conducts electricity from the appliance back to the source, completing the circuit; color-coded white or gray
7.	____________	Safety device that prevents the overload of an electrical circuit by "burning out" and interrupting the electrical flow
8.	Circuit	
9.	____________	Electrical current that changes its direction of flow at regular intervals, usually 60 times per second
10.	____________	Code sponsored by the National Fire Protection Association
11.	Amperage	
12.	Grounding	
13.	____________	Wires in the same circuit come into contact, causing the flow of electrical current to move from its desired path
14.	Wattage	

15.	_______________	Independent, not-for-profit testing and certification organization that evaluates products, materials, and systems in the interest of public safety
16.	Voltage drop	
17.	Kilowatt (kW)	
18.	_______________	Electrical current that flows steadily in the one direction through a conductor; produced by a generator or battery
19.	Resistance	
20.	_______________	Mark indicating that representative samples of a product have been tested and evaluated with reference to nationally recognized safety standards

UNIT V - ELECTRICITY

Lesson 3: Wire Types and Uses

Competency/Objective: Match types and sizes of wire with their uses.

Study Questions

1. **What are the different types of wire?**
2. **Which wires are best adapted for agricultural wiring?**
3. **Why is wire size important?**
4. **How is the right wire size selected?**
5. **What are feeder wires?**
6. **How does demand load affect the feeder wire?**
7. **How does length and voltage drop affect feeder wire size?**
8. **What are some rules of thumb to apply when calculating the circuit needs of a structure?**
9. **What is the procedure for calculating the load in an agricultural building?**

References

1. *Agricultural Structures (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit V.
2. Transparency Masters
    a) TM 3.1: Service Wire
    b) TM 3.2: Cable
    c) TM 3.3: Wire Sizes
    d) TM 3.4: Wiring Tables
    e) TM 3.5: Feeder Wires
3. Activity Sheet
    a) AS 3.1: Calculating Feeder Wire Size

Lesson 3: Wire Types and Uses

TEACHING PROCEDURES

A. *Review*

In the previous lesson, the importance of safety when working with electricity and electrical terminology were stressed. This information will now be applied to actual wiring procedures. When planning electrical systems in construction, determining the types of wires to be used is a priority. To choose the proper type of wire and wire size, it is important to be familiar with the types of wire available and the uses of each, the NEC recommendations for agriculture structures, and the electrical load to be placed on the wire.

B. *Motivation*

1. Buy different sizes of tubing (⅛", ¼", ½", ¾") from a hardware store and bring them to class. Have students answer the following questions.

    - Which tube will allow the least amount of water through?
    - Which will allow the greatest?
    - What will happen if the same amount of water carried through the ¾" tube is forced through the ¼" tube? (Increased pressure!)
    - What does this pressure create? (Friction)

2. The same principles apply to electricity and electrical wiring. Think of the tubing as the wire and the water as electricity. Just like the tubing, the goal when selecting electrical wire is to have the appropriate size to allow the needed amount of electricity to flow through it without experiencing losses in power, or voltage drop, due to excess friction throughout the path, which causes resistance to electrical flow.

C. *Assignment*

D. *Supervised Study*

E. *Discussion*

1. For a building or structure to receive electricity, power must flow through a series of different sizes and types of wire. Each type of wire is identifiable by its components and a lettering scheme. Ask the class why it is important to have different types of wires available for conducting electricity. TMs 3.1 and 3.2 can be used to illustrate cables and emphasize the different components.

    What are the different types of wire?

    a) Wire material
        1) Copper wire
            (a) Best conductor for most purposes
            (b) Most widely used
        2) Aluminum wire
            (a) Relatively poor conductor
            (b) Copper clad aluminum slightly better
            (c) Must be two sizes bigger than copper wire to produce similar results
    b) Service wires - carry power into the home or building to the service entrance panel
        1) SE - overhead installations

- 2) USE - underground service
- 3) Consist of a bundle of wires, with fine strands of uninsulated wire wrapped around the insulated wires; the uninsulated wire is the grounded neutral

c) Interior wires - must be protected from the elements

- 1) Type T
  - (a) Most commonly used interior wire type
  - (b) Has thermoplastic insulation, which is a single layer of plastic compound that covers the individual wire
  - (c) Can strip insulation off easily and cleanly, making the wire easy to use
  - (d) Divided into four categories based on the wire's ability to withstand environmental and temperature conditions
    - (1) TW - moisture resistant; may not be buried directly in the ground; maximum temperature of 140 degrees Fahrenheit
    - (2) THW - moisture and heat resistant, with a heat rating of 194 degrees Fahrenheit; may not be buried in the ground
    - (3) THHN - dry conditions; maximum temperature of 194 degrees Fahrenheit
    - (4) THHW - wet and dry conditions; maximum temperature of 194 degrees Fahrenheit in dry conditions and 167 degrees Fahrenheit in wet conditions
- 2) Type R
  - (a) Previously rubber coated for insulation but now uses synthetic polymers
  - (b) May have moisture-resistant, flame-retardant outer covering
  - (c) Rarely used in modern construction, although still found in older structures
  - (d) Has three categories of wire
    - (1) RH - dry conditions; maximum temperature of 167 degrees Fahrenheit
    - (2) RHH - dry conditions; temperature rating of 194 degrees Fahrenheit
    - (3) RHW - wet or dry conditions; temperature rating of 167 degrees Fahrenheit

d) Cables - individual wires assembled and covered with a protective element; predominant form of structural wiring used in the modern construction industry

- 1) Nonmetallic sheathed cable
  - (a) Most common type of cable used in building construction
  - (b) Contains two or three THHN or THHW wires with an additional bare ground wire
  - (c) Easy to install, clean in appearance, and highly economical
  - (d) Comes in three forms
    - (1) NM - used in dry conditions, not in barns or other damp locations on agricultural operations
    - (2) NMC - designed for damp or corrosive locations but cannot be buried underground
    - (3) UF - identical to NMC but can be buried directly underground
- 2) Armored cable
  - (a) Used in dry locations only
  - (b) Contains TW, THW, or THHN wires
  - (c) Wires enclosed in tough paper overwrap and spiral steel armor
- 3) Flexible cord
  - (a) Type SPT-2
    - (1) Wires imbedded in plastic
    - (2) Used for small appliances, such as floor lamps, radios, etc.
  - (b) Type S
    - (1) Heavier
    - (2) Used for applications where heavy use and abuse is possible, such as for power tools
    - (3) Wires bundled into a round assembly insulated with plastic or rubber
  - (c) Type HPN
    - (1) Heater cord

(2) Used for heating appliances, such as toasters and irons

2. Agriculture structures pose slightly different requirements than homes or businesses in terms of electrical work. Why?

Which wires are best adapted for agricultural wiring?

a) NEC categories of agricultural buildings
    1) Buildings where excessive dust and dust with water may accumulate
        (a) Totally enclosed and environmentally controlled poultry and livestock structures
        (b) Confinement systems where litter, dust, and feed dust may accumulate
        (c) Feed mills
    2) Buildings where a corrosive atmosphere exists - totally enclosed and environmentally controlled areas where:
        (a) Poultry and animal excrement may cause corrosive vapors in the confinement area
        (b) Corrosive particles may combine with water
        (c) The area is damp and wet because of periodic washing and sanitizing with water and cleansing agents, as is the case in milk parlors
b) Approved wires for agricultural buildings
    1) UF, NMC, and other cables or raceways that are highly resistant to corrosion
    2) In buildings with excessive dust, must have "dust-ignition-proof" wires and fixtures that do not produce arcs, sparks, or heat sufficient to cause dust to ignite

3. The size of the wire is as important as selecting the proper wire type for a job. Ask students why wire size matters. Refer back to the demonstration of the tubes in the motivation section. Show students TM 3.2 to illustrate wire size.

Why is wire size important?

a) Wire size is measured using the American Wire Gauge (AWG).
    1) Smaller AWG numbers represent larger wire sizes.
    2) Number 14 is the smallest size allowed in most structures, although the wire size used in agricultural structures should not be smaller than number 12.
    3) Wire sizes range from 4/0 (about ½ inch in diameter) to 20+.
b) Wire size is important for two reasons.
    1) Ampacity is defined as the safe carrying capacity of the wire.
        (a) The greater the amount of amperes flowing through a conductor, the greater the amount of heat produced.
        (b) Doubling the amperes without changing the wire size will increase heat output by four times.
        (c) If the amperage becomes too high for a prolonged period, it may damage the insulation and start a fire.
    2) Voltage drop is the loss of electrical pressure over a length of wire.
        (a) Some voltage drop is expected, and a 2 percent drop is acceptable, but excessive voltage drop is wasted power.
        (b) Machinery and equipment that run at lower than rated voltages work inefficiently.
        (c) Wire size affects voltage drop; a larger conductor provides a larger surface for more complete electrical flow.
        (d) If more amperes are pushed through a conductor than its size allows, increased friction results, causing heat buildup and voltage drop.

4. After electrical loads are established for each circuit, the proper wire size must be determined. Discuss how to select the proper wire size. Show the students the table on TM 3.3 and explain its use.

How is the right wire size selected?

a) Some key information is needed before the appropriate wire size can be determined.
    1) Amperage load
    2) Voltage
    3) Wattage
    4) Length of run
    5) Type of wire installation used, such as open air or buried wire, since larger wires are needed overhead for support and because of voltage leaks

b) Wire size can be determined by using amperage, voltage, wattage, and the length of the run.

    NOTE: Show the class the tables on TM 3.3 and explain how they are used to choose a wire size for a particular situation. As an example, use 30 amperes at 240 volts with a one-way distance of 120 feet, requiring a number 8 wire. Explain that different tables would be used with underground wires.

    1) Always round up calculated wattage in consideration of future growth and increased power conditions.
    2) If the distance the wire is to span falls between the distances given on the table, use the longer distance and the larger wire.

c) Beyond the basic considerations, overhead wires pose other requirements.
    1) The wires need to be large enough to support themselves without sagging and to maintain some rigidity under heavy snow loads.
    2) To carry 600 volts or less, AWG 10 is recommended for spans up to 50 feet in length; number 8 wire is needed for longer spans.
    3) To carry over 600 volts, AWG 6 is needed where individual conductors are used, and number 8 where conductors are in the form of a cable.

5. For agricultural facilities, power is brought in and distributed differently than in most homes and businesses. Ask students to explain the differences. Show students TM 3.4 to illustrate power distribution from a yard pole through feeder wires.

What are feeder wires?

a) The feeder wires span the distance from the electrical service equipment at the pole to the service panel at each individual structure.
b) They are either SE or USE wire, depending upon whether the service will be installed overhead or underground.

6. When planning to supply electrical power to outlying agriculture structures, the demand load of those structures needs to be taken into account. Ask the class to define demand load. What is the connection between demand load and feeder wire size?

How does demand load affect the feeder wire?

a) The size of the feeder wire depends on the demand load for a structure.
b) Demand load is considered to be the amount of power that will likely be needed at any given time.
c) The minimal calculated demand load is normally about 35 percent of the actual connected load.
d) Depending on the type and use of the electrical system within an agriculture structure, this percentage may be higher.
e) The approximate amperage that will be in use will determine the necessary feeder wire size.

7. Discuss the effect of wire length and voltage drop on feeder size. Have students complete AS 3.1.

   How does length and voltage drop affect feeder wire size?

   a) Because length tends to be a fixed factor once the yard pole is in place, the size of the feeder wire must then be increased to avoid voltage drop if demand loads or amperage requirements increase.
   b) A good rule of thumb is to place the pole or power source as close as possible to the building or buildings that will have the highest electrical use.

8. Discuss the guidelines that should be applied when planning the circuit requirements of a structure.

   What are some rules of thumb to apply when calculating the circuit needs of a structure?

   a) Lighting and/or convenience outlets - at least one for every 150 square feet of floor space
   b) Minimum of 3 watts of lighting for each square foot of floor space
   c) Convenience outlets installed every 12 linear feet along walls
   d) Branch circuit with a 20-amp minimum for 500 square feet of floor space
   e) Minimum of a 15-amp branch circuit for every 375 square feet of floor space
   f) Water heater - branch circuit of 30 amps, carrying 220 volts
   g) Fan - branch circuit of 20 amps, carrying 110 volts
   h) Water pump - branch circuit of 20 amps, carrying 110 or 220 volts
   i) Workshop bench - branch circuit of 20 amps, carrying 110 or 220 volts

9. Ask students what they would do to calculate the electrical load for a building. Explain the steps of the procedure for calculating load.

   What is the procedure for calculating the load in an agricultural building?

   a) List the number of circuits, special appliances, motors, etc. to be used.
   b) Determine the total volt-amperes (VA), or watts (W), for each by multiplying their amperage and voltage requirements and then multiply each one by the number of power outlets of that type.
   c) Add the numbers to determine total wattage of the structure.
   d) Multiply by the demand load factor; if in doubt about the size of the demand load, use a higher percentage.

   EXAMPLE: Use this example to demonstrate how to calculate feeder wire size. The problem given is also included in the *Agricultural Structures* student reference.

   Circuits and appliances:

   10 lighting circuits, generally calculated at 400 W
   5 outlets, generally calculated at 200 W
   3 motors, at 1200 W, 2000 W, and 3000 W
   1 heater, stamped with a rating of 5000 W

   W requirements:

   10 × 400 W = 4000 W
   5 × 200 W = 1000 W
   (1200 W + 2000 W + 3000 W) × 0.50 = 3100 W (Use .5 as a multiplier if all the motors do not run at the same time.)
   Heater = 5000 W

Total W: 4000 W + 1000 W + 3100 W + 5000 W = 13,100 W or 13.1 kW

Demand load: 13.1 kW × 0.50 = 6.55 kW, or 6550 watts

F. *Other Activities*

Using the classroom or shop, have the students determine the number and electrical requirements of lights, outlets, and equipment. Use this information to determine the volt-ampere/watt requirements of the area and the size of the feeder wire needed to connect the meter base to the service panel.

G. *Conclusion*

Choosing the correct wire type for agricultural structures is important, since certain hazards may be present if inappropriate wires are used. The size of these wires is also critical, since the electrical system may operate inefficiently if conductors are not large enough. Feeder wires are especially important, since they carry electricity from the service equipment at the yard pole to the individual structures of the farmstead. Determining the correct feeder wire size involves calculating the amount of electrical usage and the demand load of the structure.

H. *Answers to Activity Sheet*

1. TOTAL CONNECTED LOAD = 29500 W
2. DEMAND LOAD = 29500 W × .45 = 13275 W
3. WIRE SIZE = No. 6 AWG

I. *Answers to Evaluation*

1. d
2. c
3. e
4. a
5. b
6. b
7. c
8. a
9. Amperage load, voltage, wattage, length of run, and type of wire installation used
10. NMC and UF
11. Ampacity and voltage drop

12. List the number of circuits, special appliances, motors, etc. to be used.

13. Place the yard pole as close as possible to the building or buildings that will have the highest electrical use to reduce wire costs and the effects of voltage drop.

14. Demand load is typically considered to be the amount of power which will likely be needed at any given time.

UNIT V - ELECTRICITY

Lesson 3: Wire Types and Uses

Name ____________________________

Date ____________________________

EVALUATION

Match the term on the right with the description on the left.

1. ______ Heater cord
2. ______ Nonmetallic cable; corrosive areas
3. ______ Underground service cables
4. ______ Heat and moisture resistant
5. ______ Dry conditions

a. THW
b. RH
c. NMC
d. HPN
e. USE

Circle the letter that corresponds to the best answer.

6. For 500 square feet of floor space, a minimum ___________ branch circuit is required.

   a. 15-amp
   b. 20-amp
   c. 25-amp
   d. 30-amp

7. The wires that span the distance from the electrical service equipment at the pole to the service panel at each individual structure are:

   a. Cords.
   b. Demand cables.
   c. Feeder wires.
   d. Copper wires.

8. What is the minimum wattage for lighting per square foot of floor space?

   a. 3
   b. 4
   c. 5
   d. 6

Complete the following short answer questions.

9. What are the five pieces of information required to determine the wire size?

   a.

   b.

   c.

   d.

   e.

10. What are two examples of approved wires for agricultural buildings?

a.

b.

11. What are two reasons that using the proper wire size is important?

a.

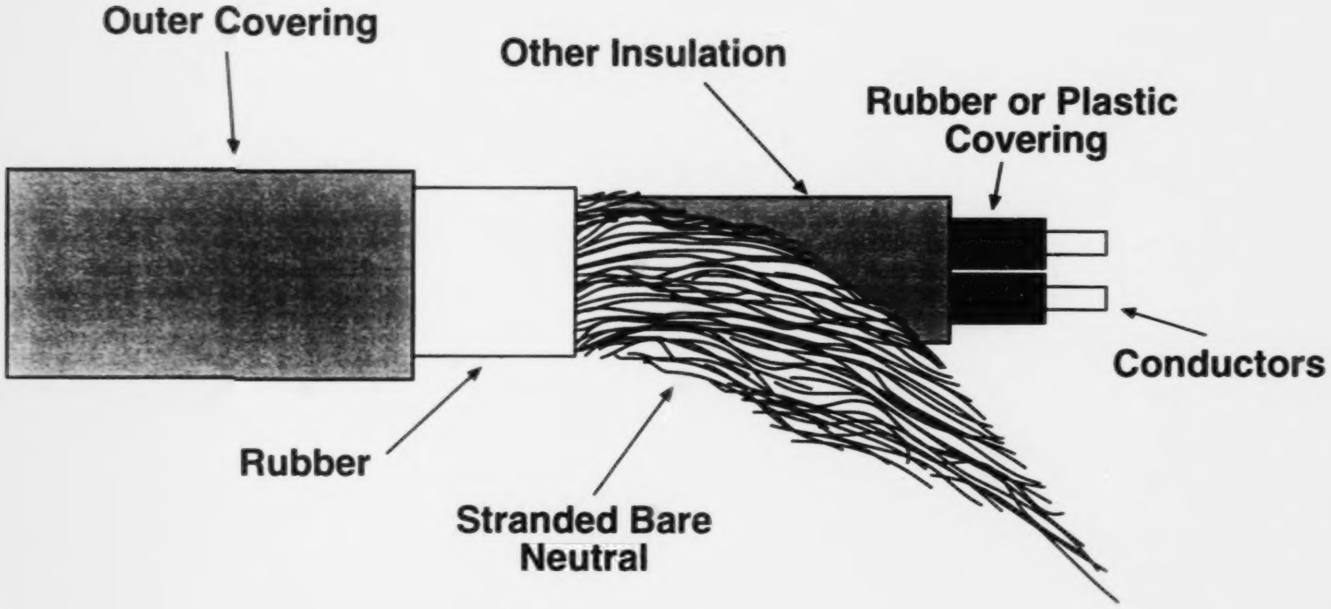
b.

12. What is the first step in calculating load for an agricultural structure?

13. Where would the electrical service pole best be located, and why?

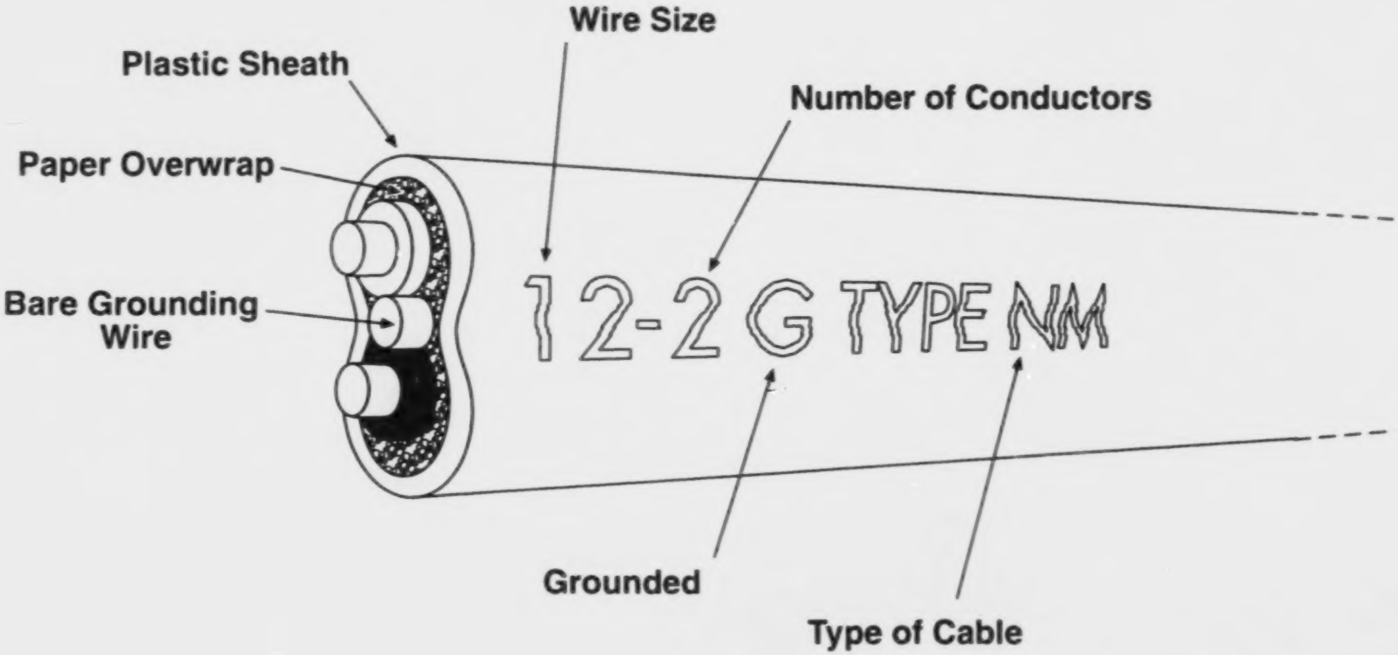
14. What is demand load?

Service Wire

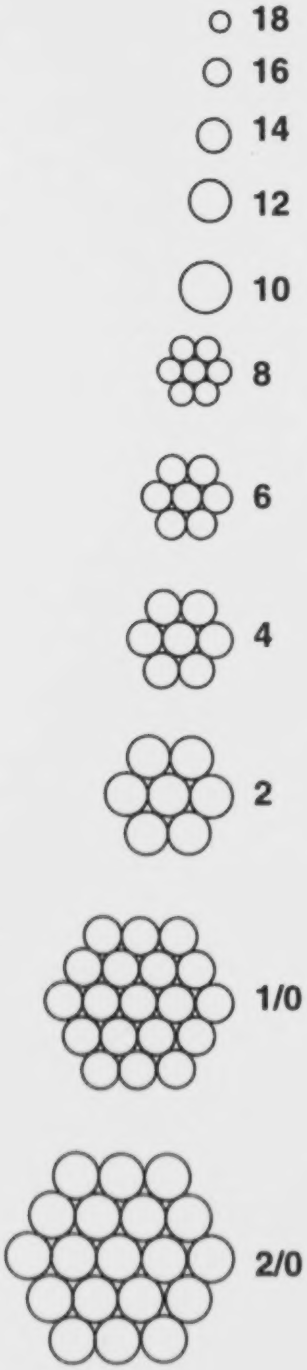

Outer Covering
Other Insulation
Rubber or Plastic Covering
Conductors
Rubber
Stranded Bare Neutral

Agricultural Structures, V-31

Cable


Wire Size
Plastic Sheath
Number of Conductors
Paper Overwrap
Bare Grounding Wire
12-2 G TYPE NM
Grounded
Type of Cable

Wire Sizes


18
16
14
12
10
8
6
4
2
1/0
2/0

Wiring Tables

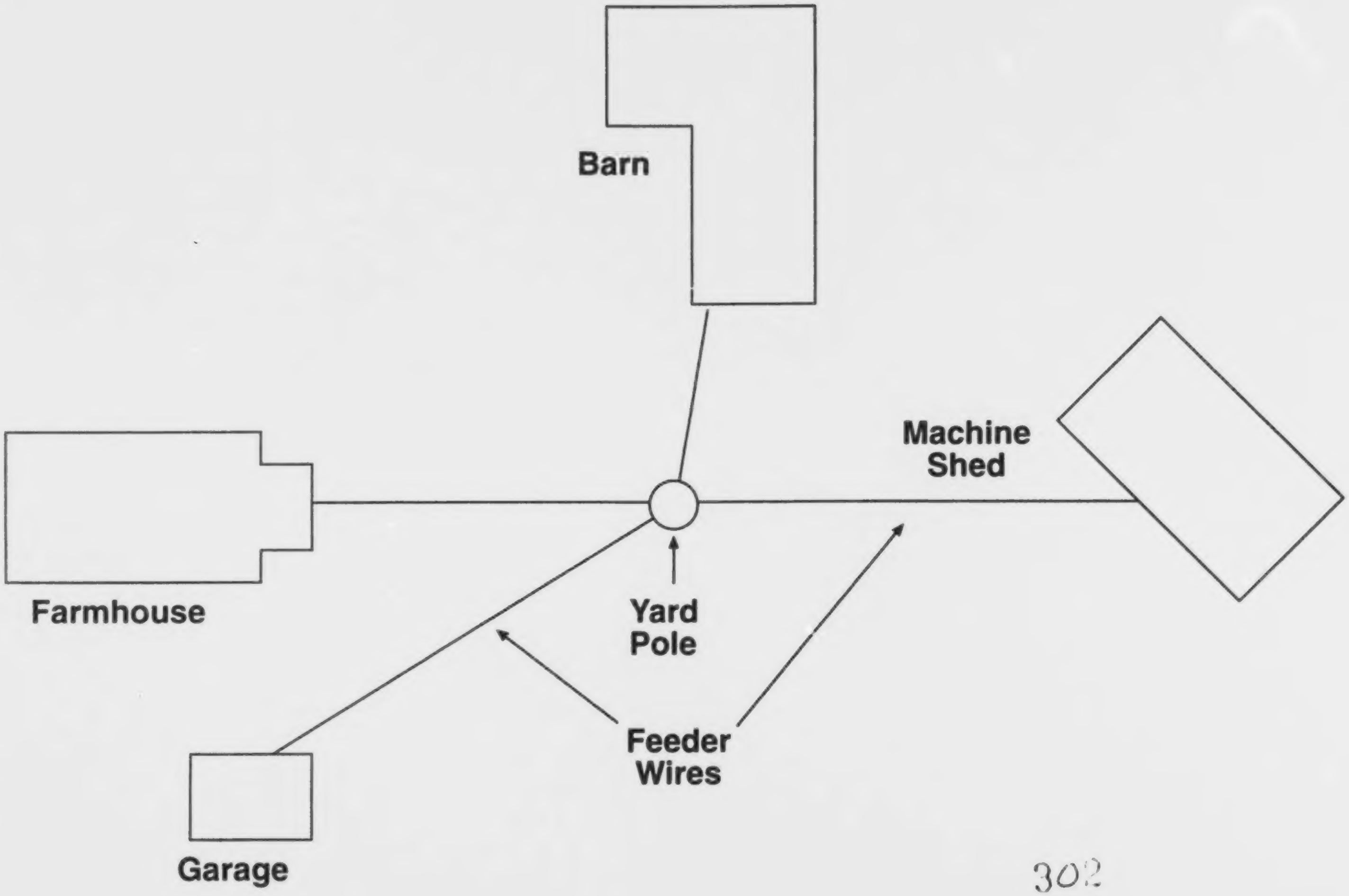
One-Way Distances (in Feet) at 120 Volts, Single-Phase, with 2% Voltage Drop

Amps	Watts	AWG Wire Sizes									
		14	12	10	8	6	4	2	1/0	2/0	3/0
5	600	90	140	225	360	570	910				
10	1200	45	70	115	180	285	455	725			
15	1800	30	45	70	120	190	300	480	765	960	
20	2400	20	35	55	90	145	225	360	575	725	915
25	3000	18	28	45	70	115	180	290	460	580	730
30	3600	15	24	35	60	95	150	240	385	485	610
40	4800			28	45	70	115	180	290	360	455
50	6000			23	36	55	90	145	230	290	365

One-Way Distances (in Feet) at 240 Volts, Single-Phase, with 2% Voltage Drop

Amps	Watts	AWG Wire Sizes									
		14	12	10	8	6	4	2	1/0	2/0	3/0
5	1200	180	285	455	720	1145					
10	2400	90	140	225	360	570	910	1445			
15	3600	60	95	150	240	380	610	970	1530		
20	4800	45	70	115	180	285	455	725	1150	1450	
25	6000	35	55	90	140	230	365	580	920	1160	1450
30	7200	30	48	75	120	190	300	480	770	970	1220
40	9600		36	56	90	140	230	360	575	725	915
50	12000			45	70	115	185	285	460	580	725
60	14400				60	95	150	240	385	485	610
70	16800				50	80	130	205	330	410	520
80	19200					70	115	180	285	360	460
90	21000					60	100	160	260	320	405
100	24000					55	90	145	230	290	365
125	30000						75	120	190	240	300
150	36000							95	150	195	245
200	48000							70	115	145	185

Feeder Wires


Barn
Machine Shed
Farmhouse
Yard Pole
Feeder Wires
Garage

Agricultural Structures, V-39

TM 3.5

UNIT V - ELECTRICITY AS 3.1

Lesson 3: Wire Types and Uses Name ____________________

Calculating Feeder Wire Size

Objective: Calculate the total connected load, the demand load, and the feeder wire size.

Using the information provided and the necessary tables from the student reference, calculate the total connected load, the demand load, and the AWG wire size for the feeder wire. Show your work.

Circuits and appliances at 240 volts:

15 lighting circuits at 400 W each
12 receptacle outlets at 200 W each
5 motors, ½, 1, 2, 2, and 4 hp
1 heater at 7000 W
2 ventilation fans at 4500 W each

Motor data:

½ hp	500 W
1 hp	1200 W
2 hp	2000 W
4 hp	4500 W

Other information:

Use 0.50 factor for electrical motors.
Use a demand load factor of 45%.
The length of the run from service pole to service panel is 75 feet.

1. TOTAL CONNECTED LOAD = __________

2. DEMAND LOAD = __________

3. WIRE SIZE = ________

UNIT V - ELECTRICITY

Lesson 4: Grounding and GFCI Protection

Competency/Objective: Identify the importance of grounding and GFCI protection.

Study Questions

1. **What is grounding, and why is it important?**
2. **What are the NEC requirements for grounding?**
3. **What are GFCIs?**
4. **What are the NEC requirements for GFCI use?**
5. **What are the types of GFCI units used in agriculture structures?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit V.
2. Transparency Masters
   - a) TM 4.1: A GFCI at Work
   - b) TM 4.2: Types of GFCIs
3. Activity Sheet
   - a) AS 4.1: Grounding and GFCIs

UNIT V - ELECTRICITY

Lesson 4: Grounding and GFCI Protection

TEACHING PROCEDURES

A. ***Review***

The last lesson discussed the importance of properly selecting wire types and sizes for agricultural structures. This lesson, Lesson 4, focuses on the importance of grounding the electrical system. The grounding of a building's electrical system is a safety feature that helps to protect people and animals from receiving a shock by redirecting the electrical current. Ground fault circuit interrupters, or GCFIs, also provide a safety feature that helps protect against electrical shock.

B. ***Motivation***

Ask students to think of electricity as a living entity that is continually searching for a means of completing its path. Electricity will always seek the path of least resistance to complete its circuit. What would happen if a person came in contact with a wire or piece of equipment that has a short? What can protect individuals from being shocked?

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Ask students to describe ways to prevent shock hazards, and list them on the board. How many are related to grounding? Ask students to define grounding. Why is it important?

   What is grounding, and why is it important?

   a) Grounding
      1) Forms the connection between a piece of equipment or electrical appliance and the earth
      2) Provides electricity an alternate path back to its source
      3) Grounding point
         (a) Typically established at or near the service entrance panel
         (b) May consist of a metal rod driven into the ground that is connected directly to the service panel with a ground wire
         (c) May also consist of a grounding wire attached to an established galvanized metal water pipe
      4) Connected to appliances and electrical equipment through a dedicated ground wire
         (a) Connected either to the equipment directly or to the electrical outlet receptacle
         (b) Leads back to the ground connection at the service panel
   b) Importance - prevention of electrical shock
      1) Provides a safety measure for channeling an electrical current that is out of the electrical circuit back to the earth at the source
      2) Directs the charge away from humans and livestock

2. The NEC has set forth guidelines related to correct procedures for safely installing a grounding system. Discuss NEC requirements for grounding.

   What are the NEC requirements for grounding?

- a) Three main purposes
    - 1) Grounding limits voltages in an electrical system due to lightning, line surges, or unintentional contact with higher voltage lines.
    - 2) It helps stabilize voltages within the system.
    - 3) It provides a path to facilitate the operation of overcurrent devices.
- b) Regulations
    - 1) Proper grounding rods must be in place and connected to the electrical system prior to making the electrical connection to the power source.
    - 2) The ground rod conductor is to be connected at the point where the electrical service enters the service panel.
    - 3) All connections to the ground rod must be made at the service panel and the entrance point to the service panel, not on the individual circuits.
    - 4) The grounding electrode should be as near as practical to the service entrance.

3. Ask students whether a ground wire can provide all the protection needed for an electrical system. What would happen if the ground wire was faulty? Describe the uses of GFCIs. Show students TM 4.1 to illustrate how GFCIs work.

What are GFCIs?

- a) GFCI (ground fault circuit interrupter) - device that interrupts the circuit to any electrical device when a fault current exceeds a predetermined level less than that required to operate the overcurrent protection device
- b) Primary function - to interrupt the flow of the current to prevent people and animals from being shocked
- c) Monitors the magnitude and time of electrical flow; interrupts abnormal electrical flows of 5/1000 amperes in 25/1000 of a second
- d) Work by sensing imbalances in electrical circuits caused by shorts or other faults
    - 1) When an imbalance occurs between the black "hot" wire and white "neutral" conductors, an uneven electrical load exists in the system.
    - 2) A ground fault current is present and seeking a return conductor to the source.
    - 3) A person or animal coming in contact with the fault current can provide this path.
    - 4) The GFCI prevents shocks by stopping the electrical flow.

4. The NEC has developed a set of guidelines that apply to the installation and use of GFCIs. Discuss the requirements of the NEC.

What are the NEC requirements for GFCI use?

Required for all outlet receptacles or any devices permanently wired into the electrical system that are installed in the locations listed

- a) Bathrooms
- b) Garages and grade level portions of unfinished accessory buildings used for storage and work areas
- c) Outdoors
- d) Crawl spaces, where the crawl space is at or below ground level
- e) Unfinished basements and areas not intended as habitable rooms and limited to storage areas, work areas, and the like
- f) Kitchens, where the receptacles are installed to serve counter top surfaces
- g) Indoor or outdoor swimming pools
- h) Hot tubs
- i) Portable signs
- j) Any location using temporary power

5. Ask students to describe any GFCIs they have seen. Describe the four types of GFCIs available for homes and farms. TM 4.2 illustrates the different types. Point out that the use of a particular

type of GFCI will be determined by the conditions of the structure. Have students complete AS 4.1.

What are the types of GFCI units used in agriculture structures?

- a) Circuit breaker
  - 1) Fixed, permanently installed
  - 2) Substitutes for a standard circuit breaker
  - 3) Controls the outlets within an entire circuit
- b) Plug-in
  - 1) Designed for use in existing electrical systems that do not have GFCI devices
  - 2) Plugs into a regular receptacle
  - 3) Protects only those appliances plugged into it
- c) Portable
  - 1) Has an extension cord and is portable
  - 2) Plugs into standard outlets
  - 3) Generally used for construction and short term circuit protection needs
- d) Outlet-type
  - 1) Permanently mounted in an outlet box
  - 2) Protects all the items plugged into it
  - 3) Widely used in the construction of new buildings

F. *Other Activities*

Have students identify various locations of GFCIs in the school. In class discuss their findings. Discuss the reasons for having GFCIs in those locations. Were there any locations where GFCIs should have been installed but were not?

G. *Conclusion*

Grounding and GFCIs are an important safety feature for electrical systems in agricultural structures. Because they are so important, the NEC requires their use to help protect humans and livestock from shocks from faulty or damaged wiring. They also work to protect the electrical system from hazardous overloads.

H. *Answers to Evaluation*

1. d
2. c
3. a
4. a
5. b
6. Ground fault circuit interrupter

7. It provides a safety measure for channeling an electrical current that is out of the electrical circuit back to the earth at the source, directing the charge away from humans and livestock.

8. Answers may include any one of the following: grounding limits voltages in an electrical system due to lightning, line surges, or unintentional contact with higher voltage lines; it helps stabilize voltages within the system; and it provides a path to facilitate the operation of overcurrent devices.

9. At the point where the electrical service enters the service panel

10. Answers may include any three of the following: bathrooms; garages and grade level portions of unfinished accessory buildings used for storage and work areas; outdoors; crawl spaces, where the crawl space is at or below ground level; unfinished basements and areas not intended as

habitable rooms and limited to storage areas, work areas, and the like; kitchens, where the receptacles are installed to serve counter top surfaces; swimming pools; hot tubs; portable signs; and any location using temporary power.

UNIT V - ELECTRICITY Name ______________________

Lesson 4: Grounding and GFCI Protection Date ______________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. The outlet-type GFCI:

   a. Controls the outlets within an entire circuit.
   b. Has an extension cord.
   c. Plugs into standard outlets.
   d. Is permanently mounted in an outlet box.

2. The grounding electrode should be:

   a. Close to all of the major appliances.
   b. Connected to each of the individual circuits.
   c. As near as practical to the service entrance.
   d. Outside of the agricultural structure.

3. How does a GFCI work to prevent shocks?

   a. By interrupting the flow of the current.
   b. By serving as a path between electricity and its source.
   c. By directing a charge into the ground.
   d. By allowing electricity to escape out of the outlet.

4. The ________________ ground fault has an extension cord attached to it.

   a. Portable
   b. Plug-in
   c. Outlet-type
   d. Circuit breaker

5. The ________________ ground fault controls the outlets in an entire circuit.

   a. Outlet-type
   b. Circuit breaker
   c. Plug-in
   d. Portable

Complete the following short answer questions.

6. What does GFCI mean?

7. Why is grounding important in the prevention of electrical shock hazards?

8. What is one of the purposes of grounding, according to the NEC?

9. According to NEC regulations, where should the ground rod conductor be connected?

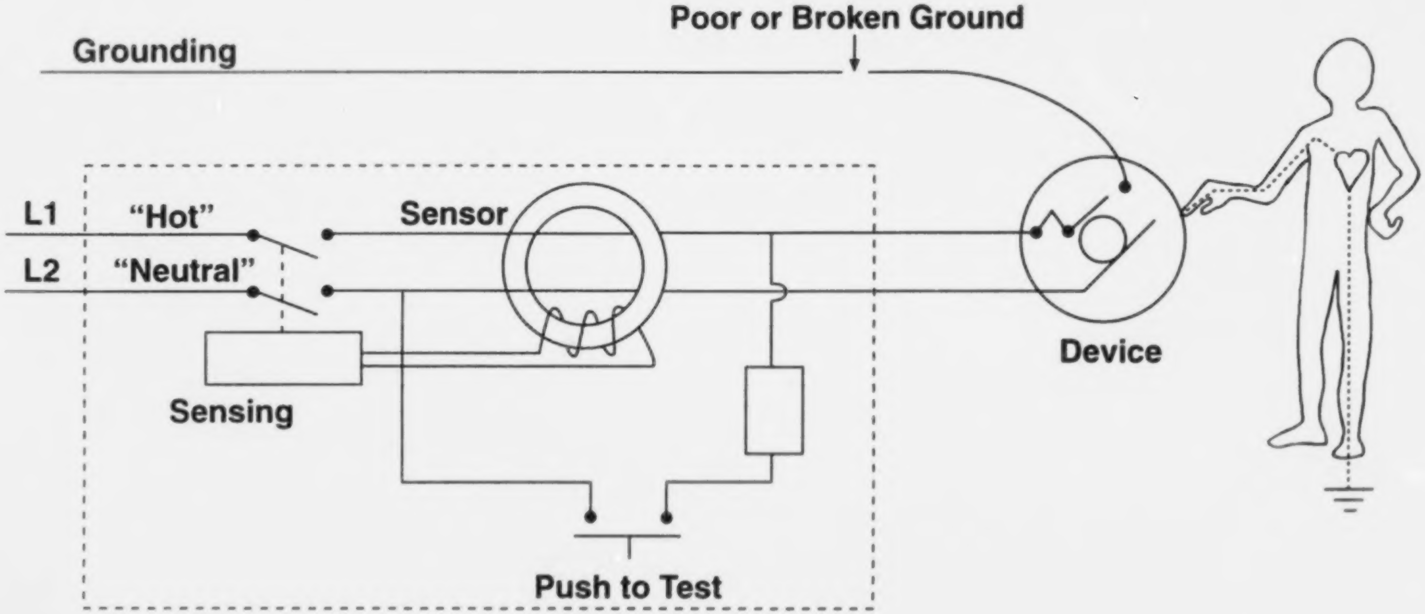
10. Where are three places the NEC requires that GFCIs be used?

    a.

    b.

    c.

A GFCI at Work

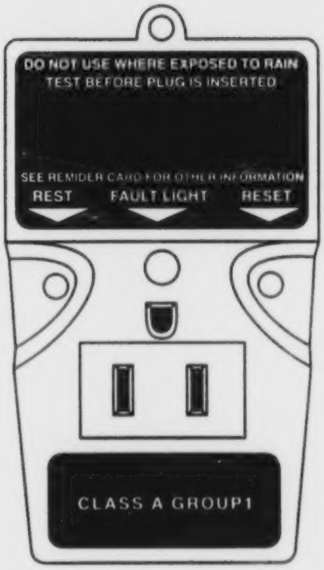

Poor or Broken Ground
Grounding
L1
"Hot"
L2
"Neutral"
Sensor
Sensing
Device
Push to Test

Agricultural Structures, V-51

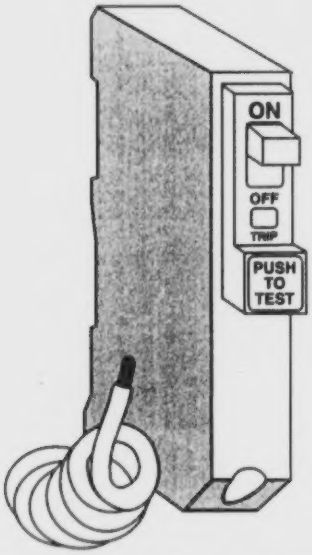
TM 4.1

TM 4.2

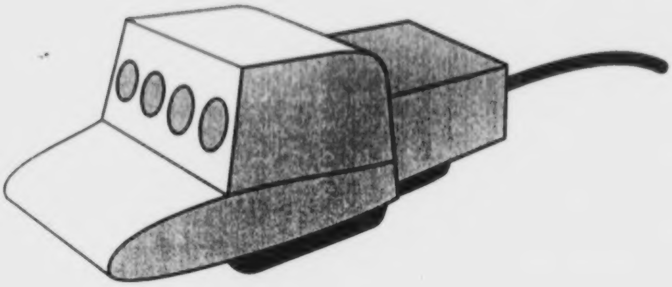
Types of GFCIs


DO NOT USE WHERE EXPOSED TO RAIN
TEST BEFORE PLUG IS INSERTED
SEE REMIDER CARD FOR OTHER INFORMATION
REST
FAULT LIGHT
RESET
CLASS A GROUP1

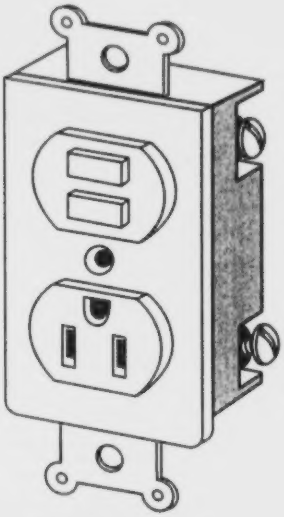
Plug-In Ground Fault


ON
OFF
TRIP
PUSH TO TEST

Circuit Breaker Ground Fault



Portable Ground Fault



GFCI Outlet

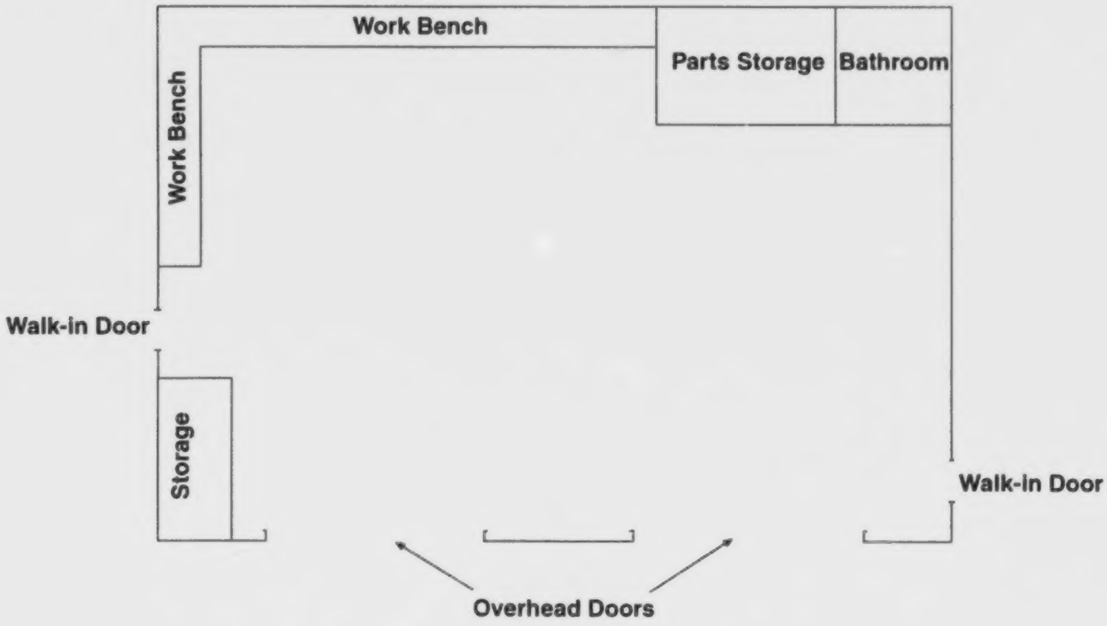
Lesson 4: Grounding and GFCI Protection Name ______________________

Grounding and GFCIs

Objective: Identify sources of electrical grounding and the location of GCFIs around the home and farm.

In the space below is a diagram of a simple machine shop. On the diagram, identify the ideal position for the electrical service panel (ESP), ground rods (GR), and installed GFCIs, using the abbreviations given.

Machine Shop 60 X 80


Work Bench
Parts Storage
Bathroom
Work Bench
Walk-in Door
Storage
Walk-in Door
Overhead Doors

UNIT V - ELECTRICITY

Lesson 5: Lights, Outlets, Switches, and Circuit Protection

***Competency/Objective*:** Locate lights, outlets, and switches, and identify circuit protection needs.

Study Questions

1. **What are the rules for lighting outlets located in an agriculture structure?**
2. **What are the types of lighting and their uses?**
3. **What are the rules for convenience outlets located in an agriculture structure?**
4. **What are the rules for switches located in an agriculture structure?**
5. **What electrical protection is needed in an agricultural structure?**
6. **What are the general recommendations for branch circuits?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit V.
2. Activity Sheet
    a) AS 5.1: Evaluating Lights, Outlets, Switches, and Circuit Protection

Lesson 5: Lights, Outlets, Switches, and Circuit Protection

TEACHING PROCEDURES

A. ***Review***

In Lesson 4, proper grounding practices and GFCI use was discussed. Another important aspect of the installation of electrical wiring in an agricultural structure is planning the number and type of lights, outlets, and switches.

B. ***Motivation***

Ask students if they know what a dust explosion is. What leads to dust explosions in agriculture structures? Discuss ways to avoid these problems, focusing particularly on items such as lights, switches, and outlets.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. When planning the wiring of an agricultural structure, it is important to follow safety standards from the NEC and local regulatory agencies. Discuss the general guidelines for lighting outlets.

   What are the rules for lighting outlets located in an agriculture structure?

   a) Wet areas - nonmetallic light fixture made of nonconductive materials, such as porcelain, plastic, or rubber
   b) Areas where dust is a problem - dust-tight light fixtures that prevent combustible materials from coming into contact with electrical connections

2. Another important consideration is the type of lighting to be used in the structure. In order to choose the most appropriate type, it is necessary to be familiar with the different types of lighting. Ask students to list the types of lighting they have seen. Discuss the different types and their uses.

   What are the types of lighting and their uses?

   a) Incandescent lamp - produces light when electricity moves through a wire filament that then glows at a white heat
   b) Gaseous discharge lamps - pass an electric current through a gas enclosed under pressure in a tube or bulb, producing light when the current moves through the gas particles
      1) Low pressure gaseous discharge lamps
         (a) Fluorescent lamps
            (1) Made up of a glass tube that contains mercury vapor and argon gas
            (2) Ultraviolet energy produced by electricity flowing through the mercury vapor; turns to visible light after striking the fluorescent coating of phosphors on the inside of the tube
            (3) Used indoors
            (4) Used effectively for supplementary lighting in greenhouses
         (b) Low pressure sodium lamps
            (1) Consist of two glass tubes, one inside the other

            (2) Inner tube - contains solid sodium and a mixture of argon and neon gas
            (3) Outer tube - protective barrier for the lamp
            (4) Gives off a yellow light
            (5) Commonly used for street lights
    2) High pressure gaseous discharge lamps
        (a) Mercury vapor lamps
            (1) Two-bulb configuration
            (2) Inner bulb - quartz arc tube containing mercury vapor at a high pressure, which allows it to produce visible light without phosphors
            (3) Produces greenish-blue light
            (4) Longer life than other lamps of similar wattage
            (5) May take 5 to 7 minutes for vapor pressure to build up and reach full brightness
            (6) Primarily used outdoors around farms and homes
        (b) Metal halide lamps
            (1) Contain compounds of metal and halogen with the same basic two-bulb design
            (2) Produce more naturally colored light
            (3) Long life and high light output
            (4) Excellent outdoor light source
            (5) Some indoor applications as well, such as supplementary lighting for greenhouses
        (c) High pressure sodium lamps
            (1) Similar to mercury vapor lamps
            (2) Arc tube made of aluminum oxide containing a solid mixture of sodium and mercury
            (3) Produce an orange-white light
            (4) Long life and very high light output
            (5) Used outside around homes and farms

3. A sufficient number of convenience outlets must be included in an agricultural structure. Have students observe the number of convenience outlets in the classroom and the spacing between them. Discuss the guidelines for their installation.

What are the rules for convenience outlets located in an agriculture structure?

a) Location
    1) Installed where animals will not readily bump into them; should be at least 5 feet above ground level anywhere livestock may be present
    2) Must be easily accessible
    3) Mounted between the studding or flush with the wall
b) Type
    1) 20-amp duplex receptacles with a safety ground
    2) GFCI receptacle preferable, especially in damp areas
    3) Nonmetallic outlet boxes
c) Number
    1) Depends on the amount of use the outlet will receive and the building type
        (a) Livestock buildings - 12 to 15 feet between outlets
        (b) Other structures - 8 to 10 feet
    2) Rule of thumb - to install enough outlets so that extension cords will not have to be used on a regular basis

4. Switches control everything from lighting to motorized equipment. Discuss the use of switches in agricultural structures.

What are the rules for switches located in an agriculture structure?

a) Location based on convenience and ease of access
b) Installed at elbow height in protected spots
c) On the latch side of doors and on the traffic side of arches
d) Need multiple switches when multiple doors provide access to a single room or bay, if the doors are farther than 10 feet apart

5. Because of the damp and corrosive environments found in agricultural structures, electrical protection is a priority in these buildings. Describe the types of electrical protection needed.

What electrical protection is needed in an agricultural structure?

a) Branch circuits - need adequate amperage-rated fuses or circuit breakers, which is calculated based on the anticipated use of the circuit
b) Grounding
    1) Needed for all noncurrent carrying devices
    2) System ground wire - same size as the wires carrying electrical current

6. Branch circuits are the primary electrical connections within agricultural structures. Therefore, it is very important to carefully plan these circuits. Discuss the recommendations for branch circuits. Have students complete AS 5.1. Point out that older structures may not meet the current standards described in this lesson, although they may not be unsafe.

What are the general recommendations for branch circuits?

a) Must have enough circuits to carry out business efficiently
    1) General purpose circuits must be considered in planning.
        (a) Permanent lighting circuits
        (b) Convenience outlets
        (c) Special lighting circuits like automatic on/off outdoor lights
        (d) Portable heater units
    2) The service entrance panel should have open circuit spaces for anticipated electrical expansion.
b) Limitations
    1) Branch circuits should not operate at more than 2 percent voltage drop or use wire smaller than AWG 12.
    2) The electrical load is not to exceed 80 percent of the branch circuit rating.
    3) Fixed appliances must not be over 50 percent of the load if lighting is also included on the circuit.

F. *Other Activities*

Have students identify the branch circuits and the outlets they control in the agriculture building by examining the labeling on the service entrance panel.

G. *Summary*

When planning the electrical system of an agriculture structure, identifying the lighting, outlet, and switch requirements for that building is crucial. The materials installed should be designed for the typical uses and environmental conditions of the structure. Careful planning is required to design a system that will meet current and future demands.

H. *Answers to Activity Sheets*

I. *Answers to Evaluation*

1. d
2. e

3. a
4. b
5. c
6. f
7. To prevent combustible materials from coming into contact with electrical connections
8. 12 to 15 feet in livestock buildings, 8 to 10 feet in others
9. The same size as the wires carrying electrical current
10. Answers may include any two of the following: permanent lighting circuits, convenience outlets, special lighting circuits, and portable heater units.

UNIT V - ELECTRICITY Name ____________________

Lesson 5: Lights, Outlets, Switches, and Circuit Protection Date ____________________

EVALUATION

Match the lamp types on the right with the descriptions on the left.

1. _____ Contains compounds of metal and halogen
2. _____ Produces an orange-white light
3. _____ Uses a filament that produces light under high heat
4. _____ Converts ultraviolet light into visible light
5. _____ Produces greenish-blue light
6. _____ Contains sodium, argon, and neon

a. Incandescent

b. Fluorescent

c. Mercury vapor

d. Metal halide

e. High pressure sodium

f. Low pressure sodium

Complete the following short answer questions.

7. Why should dust-tight light fixtures be used in areas where dust is a problem?

8. How far apart should convenience outlets be placed in livestock buildings? In other structures?

9. What size wire should be used to ground the system in agricultural structures?

10. What are three general purpose circuits to be considered when planning branch circuits?

    a.

    b.

    c.

Lesson 5: Lights, Outlets, Switches, and Circuit Protection Name ____________________________

Evaluating Lights, Outlets, Switches, and Circuit Protection

Objective: Observe the existing lights, outlet, switches, and circuit protection in an agricultural structure and determine if they meet the recommendations presented in class.

Observe the electrical system of an agricultural structure, such as a barn, machine shed, etc., looking at the lighting, outlets, and switches. Answer the following questions to determine if the electrical system meets NEC recommendations.

Type of Structure: ____

1. Are the lighting fixtures appropriate for the type of structure?

2. Is there adequate lighting for this structure, based on light type?

3. How many convenience outlets are present?

4. Are the convenience outlets in the recommended positions?

5. Are switches provided in convenient locations? Are multiple switch systems set up?

6. How many outlets, both light and convenience, are found on each branch circuit? (Hint: Look at the labels found on the inside cover of the SEP panel.)

7. Using the information from Lesson 2 of this unit, calculate the branch circuit loads (lights, outlets, other equipment, and motors). Is the circuit protection for these branch circuits adequate?

UNIT V - ELECTRICITY

Lesson 6: Electrical Symbols in Wiring Plans

***Competency/Objective*:** Identify the symbols used in agricultural wiring plans.

Study Questions

1. **Which symbols are used to indicate lighting, receptacle, and switch outlets?**
2. **Which symbols are used to indicate power, fusing, and grounding?**
3. **Which symbols are used to indicate panelboards, switchboards, and related equipment?**
4. **Which symbols are used to indicate remote control stations for motors or other equipment?**
5. **Which symbols are used to indicate miscellaneous connections?**

References

1. *Agriculture Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit V.
2. Transparency Master
    a) TM 6.1: Electrical Wiring Symbols
3. Activity Sheet
    a) AS 6.1: Diagramming Electrical Wiring

UNIT V - ELECTRICITY

Lesson 6: Electrical Symbols in Wiring Plans

TEACHING PROCEDURES

A. ***Review***

Lesson 5 discussed guidelines for lights, outlets, switches, and circuit protection in agricultural structures. Before one can begin to install these items, a wiring plan must be developed. A set of symbols is used to stand for the different aspects of electrical systems shown on these plans.

B. ***Motivation***

Ask students what electrical items in the classroom would be identified in a wiring schematic. Discuss the importance of planning the placement of those devices in the overall wiring process.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. The use of symbols is a standardized method of identifying the location of electrical components. Familiarity with the symbols is necessary for being able to read plans and correctly install electrical components. Discuss the symbols commonly used for lighting, receptacle, and switch outlets. TM 6.1 can be used throughout the lesson to illustrate the symbols used on plans.

   Which symbols are used to indicated lighting, receptacle, and switch outlets?

   a) Lighting outlets
      1) Ceiling
         (a) Surface or pendant incandescent or similar lamp fixture
         (b) Surface or pendant individual fluorescent fixture
         (c) Surface or pendant continuous row fluorescent fixture
         (d) Blanked outlet
         (e) Junction box
      2) Wall
   b) Receptacle outlets
      1) Single
      2) Duplex
      3) Triplex
      4) Duplex - split wired
      5) Single special purpose
      6) Double special purpose
      7) Range outlet
      8) Clock hanger
   c) Switch Outlets
      1) Single-pole (SPST)
      2) Double-pole (DPST)
      3) Three-way (SPDT)
      4) Four-way (DPDT)
      5) Switch and pilot lamp
      6) Switch and single receptacle
      7) Switch and double receptacle
      8) Door switch

    9) Time switch
    10) Ceiling pull switch

2. In wiring diagrams, it is also necessary to identify the power source and fusing and grounding locations.

   Which symbols are used to indicate power, fusing, and grounding?

   a) Electric motor
   b) Electric generator
   c) Power transformer
   d) Electric watt-hour meter
   e) Circuit breaker
   f) Fusible element
   g) Ground

3. When planning for agricultural wiring, identifying the location of the service entrance panel and any specialized switches is also necessary. Point out the different symbols used for these components.

   Which symbols are used to indicate panelboards, switchboards, and related equipment?

   a) Surface-mounted panelboard and cabinet
   b) Motor or other power controller
   c) Externally operated disconnection switch
   d) Combination controller and disconnection means

4. Agricultural structures tend to utilize more motorized equipment than the home or other types of businesses. Therefore, symbols are frequently used to indicate specialized wiring and switches for motors.

   Which symbols are used to indicate remote control stations for motors or other equipment?

   a) Push-button station
   b) Float switch - mechanical
   c) Limit switch - mechanical
   d) Pneumatic switch - mechanical
   e) Thermostat

5. Because of the environmental and physical considerations of agricultural structures, it is necessary to identify electrical devices designed to provide protection. TM 6.1 shows some of these symbols. Have students complete AS 6.1.

   Which symbols are used to indicate miscellaneous connections?

   a) Weather proof
   b) Water tight
   c) Dust tight
   d) Grounded
   e) Vapor tight
   f) Rain tight
   g) Explosion proof
   h) Recessed

F. ***Other Activities***

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Show students an actual wiring diagram of the classroom or mechanics laboratory discussed in the motivation. Discuss how their previous observations matched, or did not match, what is identified on the diagram.

G. ***Conclusion***

To successfully wire a structure, reading electrical wiring diagrams is required. The key to using these diagrams is identifying electrical symbols for the different components of the electrical system.

H. ***Answers to Activity Sheet***

I. ***Answers to Evaluation***

1. g
2. l
3. e
4. c
5. j
6. a
7. b
8. d
9. h
10. f

UNIT V - ELECTRICITY

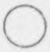
Lesson 6: Electrical Symbols in Wiring Plans

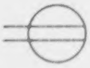
Name ______________________________

Date ______________________________

EVALUATION

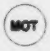
Match the symbol on the left with the terms on the right.

1. _____ 

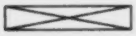
2. _____ 

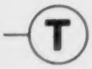
3. _____ **S**

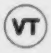
4. _____ **S**$_p$

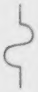
5. _____ 

6. _____

7. _____ 

8. _____ 

9. _____ 

10. _____ 

a. Ground

b. Power controller

c. Switch with pilot lamp

d. Thermostat

e. Single-pole switch

f. Fusible element

g. Surface lighting element

h. Vapor tight

I. Duplex receptacle

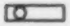
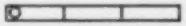
j. Motor connection

Electrical Wiring Symbols

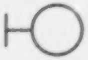
Agricultural Structures, V-75

Lighting Outlets

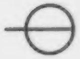
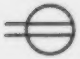
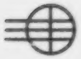
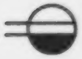
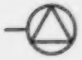
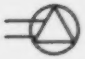
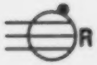
Ceiling

○	Surface or Pendant Incandescent or Similar Lamp Fixture
	Surface or Pendant Individual Fluorescent Fixture
	Surface or Pendant Continuous Row Fluorescent Fixture
Ⓑ	Blanked Outlet
Ⓙ	Junction Box

Wall

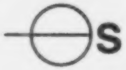
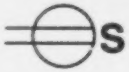
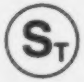
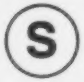
	To indicate wall installation of above outlets, place circle near wall and connect with line as shown.

Receptacle Outlets

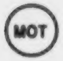
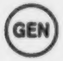
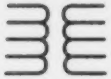
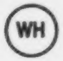
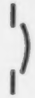
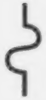
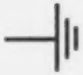
	Single Receptacle Outlet
	Duplex Receptacle Outlet
	Triplex Receptacle Outlet
	Duplex Receptacle Outlet - Split Wired
	Single Special-Purpose Receptacle Outlet
	Duplex Special-Purpose Receptacle Outlet
	Range Outlet
Ⓒ	Clock Hanger Receptacle

TM 6.1

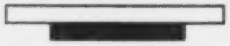
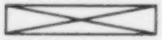
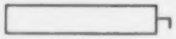
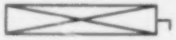
Switch Outlets

S	Single-Pole Switch (SPST)
S_2	Double-Pole Switch (DPST)
S_3	Three-Way Switch (SPDT)
S_4	Four-Way Switch (DPDT)
S_p	Switch and Pilot Lamp
	Switch and Single Receptacle
	Switch and Double Receptacle
S_d	Door Switch
	Time Switch
	Ceiling Pull Switch

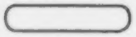
Power, Fusing, Ground

	Electric Motor
	Electric Generator
	Power Transformer
	Electric Watt-Hour Meter
	Circuit Breaker
	Fusible Element
	Ground

Panelboards, Switchboards, and Related Equipment

	**Surface-Mounted Panelboard and Cabinet**
	**Motor or Other Power Controller**
	**Externally Operated Disconnection Switch**
	**Combination Controller and Disconnection Means**

Remote Control Stations for Motors or Other Equipment

	**Push-Button Station**
F	**Float Switch - Mechanical**
L	**Limit Switch - Mechanical**
P	**Pneumatic Switch - Mechanical**
-(T)	**Thermostat**

Connections

(WP)	**Weatherproof**
(WT)	**Watertight**
(DT)	**Dust Tight**
(G)	**Grounded**
(VT)	**Vapor Tight**
(RT)	**Rain Tight**
(EP)	**Explosion Proof**
(R)	**Recessed**

Agricultural Structures, V-79

TM 6.1 (Cont.)

Lesson 6: Electrical Symbols in Wiring Plans Name ____________________________

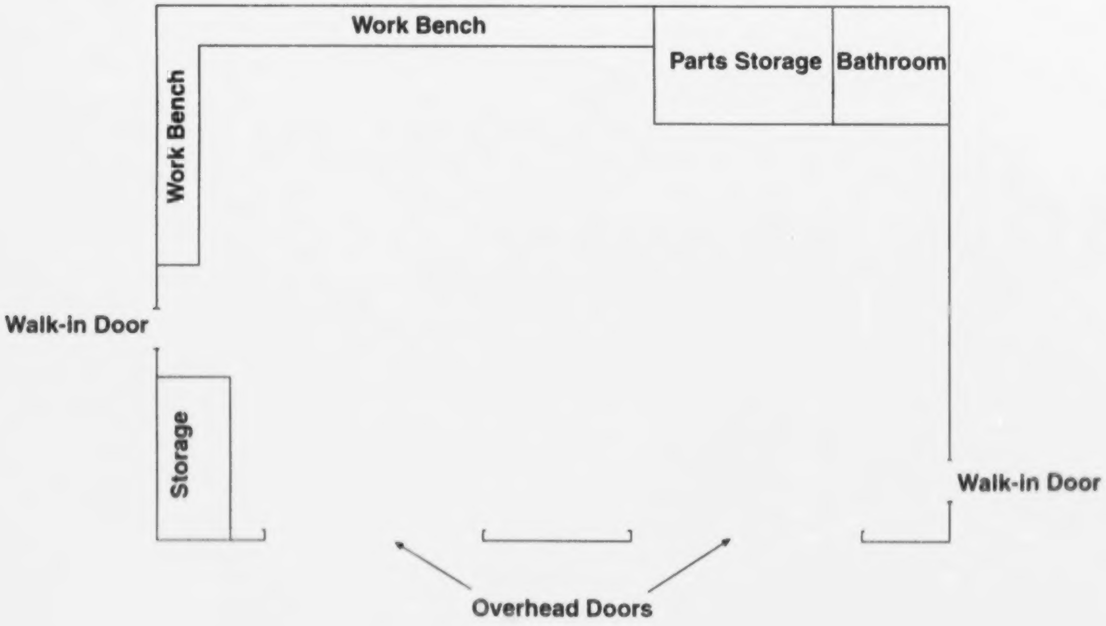
Diagramming Electrical Wiring

Objective: Diagram a wiring plan for an agricultural structure.

Draw the symbols for the fixtures listed below in the appropriate area of the machine shop diagram. You will choose where the entrances are located. Draw a line from the switches used to the fixtures controlled.

- 4 ceiling light fixtures
- 6 wall mount light fixtures
- 4 duplex receptacles (GFCI)
- Wall switches (you decide how many)

Machine Shop 60 X 80


Work Bench
Parts Storage
Bathroom
Work Bench
Walk-in Door
Storage
Walk-in Door
Overhead Doors

UNIT V - ELECTRICITY

Lesson 7: Running Electrical Wiring

Competency/Objective: Describe practices for running wire to an agricultural structure and wiring within the building safely.

Study Questions

1. **What is the configuration at the pole?**
2. **How is the service entrance installed?**
3. **When would branch circuits be used on agricultural structures?**
4. **What must be considered when wiring a barn?**
5. **What must be considered when wiring a hay barn?**
6. **How are switches and receptacles selected?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit V.
2. Transparency Masters
    a) TM 7.1: Wire Stacking at the Pole
    b) TM 7.2: Installation of the Service Entrance
3. Activity Sheet
    a) AS 7.1: Diagramming the Service Stack

Lesson 7: Running Electrical Wiring

TEACHING PROCEDURES

A. ***Review***

Planning is an important step in correctly installing an electrical system. As discussed in Lesson 6, prior to installing a single wire, a written diagram should be drawn utilizing the proper wiring symbols to identify electrical components. Wiring can take place when the diagram is complete. Wiring begins with bringing the electrical service in at the yard pole and then installing wiring from the yard pole to the service entrance of a structure. The wire can then be run within the structure to branch circuits and electrical fixtures.

B. ***Motivation***

Show students how service wires enter the agricultural education building at school. Discuss the method of attaching service wires to the SEP.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. The electrical service pole is the central hub for power distribution on agricultural operations. The installations made at the yard pole, main service entrance, and the meter should be done by an electrical contractor or the power company to be sure that they are done properly. However, understanding the configuration at the pole is important. Discuss the configuration, using TM 7.1 to illustrate the various components.

What is the configuration at the pole?

a) Three wires bring electricity in from the power company, including two hot wires and one neutral wire.
b) The grouping of the wires at the pole is called the stack.
    1) Single stack - Wires that travel into the meter from the power company and those wires traveling out to individual structures are both contained within a single conduit.
    2) Double stack
        (a) Supply wires coming in from the power company use a separate conduit from the wires that lead out to the individual structures.
        (b) Double stacking is utilized when a large number of structures are being served by one meter.
c) A separate ground wire connected to the neutral wires runs along the outside of the conduit to a ground rod.
d) All of the wires carrying power in to or out from the pole are connected directly to the pole with insulators.
    1) Requires two racks of insulators with three insulators per rack, one rack for incoming wires and the other for outgoing wires
    2) Anchored with heavy lag screws and at least one through bolt inserted through the pole for added strength
e) Feeder wires are used to carry power to the meter base.
    1) Attached to supply wires with solderless connectors
    2) Enter the conduit through the service head
    3) Run down the conduit and then attach directly to meter base

f) Short feeder wires are attached from the meter base to the main power disconnect switches at the pole.

g) The size of the feeder and supply wires traveling from the disconnect switches to the structures will be determined by each structure's demand load.

2. Once the wires are in place at the yard pole, the service entrance needs to be installed. Discuss the installation of the service entrance, using TM 7.2 as an illustration. Hand out AS 7.1.

How is the service entrance installed?

- a) Size and type of wire
  - 1) According to the NEC, AWG 8 wire is allowed if up to two two-wire circuits are being installed.
  - 2) AWG 6 is allowed if up to five two-wire circuits are being installed.
  - 3) For bigger systems, amperage calculations and wire size tables are needed to determine the proper wire size.
- b) Two-wire or three-wire type service
  - 1) A two-wire system has 110 volts available for use, which is acceptable for small sheds or buildings that will have only lights or outlet receptacles in use.
  - 2) A three-wire system has both 110 and 220 volts available for use within the structure to provide electricity for equipment requiring 220 volts.
- c) Location of the service entrance
  - 1) The location of the SEP should be determined prior to running wires from the power pole.
  - 2) NEC guidelines indicate that the SEP should be as close as practical to the point where wires enter the building.
  - 3) If possible, the service box should be near equipment that requires higher 220-volt electrical loads.
  - 4) The SEP should be installed in a location that is easily accessible.
- d) Wire connections at the building
  - 1) Insulators are connected to the structure for overhead runs of wire.
  - 2) The feeder wires connect to main wires and then run into the service head, through the conduit, and into the service entrance panel (SEP).

3. Ask students what branch circuits are used for. Discuss when they are used in agricultural structures.

When would branch circuits be used on agricultural structures?

- a) The type of structure and its use will determine the number of circuits needed.
  - 1) Small sheds with lighting
    - (a) Need only two branch circuits
    - (b) Allows for backup lights if one circuit blows
  - 2) Larger structures, such as shops and barns
    - (a) Typically need 110/220-volt service
    - (b) 220-volt outlet - requires a separate circuit made by combining two 110-volt circuits at the service entrance panel
    - (c) Varying number of circuits depending on the number of electrical systems and the number and type of appliances used
- b) When determining the number of circuits needed, careful calculations of the wattage used by all electrical components are necessary.
- c) A good rule of thumb is to add additional circuits and break up the system to avoid overload problems.
- d) Planning for expansion is also important when installing the SEP and calculating the need for branch circuits.

4. Most agricultural structures have uses that must be taken into account when planning electrical wiring. Ask students what might be considered when wiring a barn.

   What must be considered when wiring a barn?

   a) Environmental conditions
      1) Barns naturally have damp and corrosive environments and tend to lack proper ventilation.
      2) NCM or UF cable is required along with nonmetallic junction boxes that resist moisture.
   b) Mechanical damage
      1) Running wires along the sides of beams and joists to where fixtures are located provides protection.
      2) Wires are also run in protective conduits.
   c) Lighting, switches, and receptacles
      1) Plenty of lighting should be included throughout the barn.
      2) Switches should be easily accessible and mounted at elbow height.
      3) Receptacles should be dust tight, watertight, and corrosion resistant.
      4) Installing GFCI outlets is a good idea.
   d) Livestock considerations
      1) Lights, outlets, and switches should be out of the reach of livestock.
      2) This practice will prevent damage to equipment, fire hazards, and shock hazards.

5. Discuss the considerations that affect wiring in hay barns.

   What must be considered when wiring a hay barn?

   a) The dust produced by hay is highly flammable, so precautions must be taken to prevent electrical sparks from coming in contact with the dust.
   b) Wires must be enclosed in conduits or within a wall covered with sheathing.
   c) Vapor proof fixtures seal out dust from electrical connections.
   d) Lighting fixtures should minimize the entrance of dust as well as foreign matter, moisture, and corrosive materials into the exposed wiring areas.
      1) Fixtures exposed to physical damage must be protected by a guard.
      2) Fixtures exposed to water must have watertight protective coverings.

6. Proper switches and receptacles must be used when wiring agricultural structures. Ask students what characteristics these fixtures should have.

   How are switches and receptacles selected?

   a) The NEC requires that switches, circuit breakers, motor controllers, fuses, push buttons, relays, and similar devices be protected from environmental and physical damage.
   b) These components should have weatherproof, corrosion resistant enclosures designed to minimize the entrance of dust, water, and corrosive elements.
   c) Switches and receptacles designed for outdoor use may be useful because these components tend to be durable and provide protection from environmental conditions.

F. Other Activities

Invite a certified electrician to discuss the selection and installation of electrical devices in agricultural structures.

G. *Conclusion*

The connections at the yard pole and service entrance panel must be made correctly, so they should be installed only by trained professionals. Other wiring within agricultural structures can be done by nonprofessionals. However, in order to install wiring properly, they must take into account the number of branch circuits needed, the conditions in the structures that will affect wiring, and the measures needed to protect wiring.

H. ***Answers to Activity Sheet***

I. ***Answers to Evaluation***

1. b
2. a
3. c
4. To prevent damage to equipment, fire hazards, and shock hazards
5. Because it is highly flammable
6. Because they are durable and provide protection from environmental conditions
7. As close as practical to the point where wires enter the building

8. Wires in to the meter and out to the structures run through a single conduit in a single stack and through different conduits in a double stack.

UNIT V - ELECTRICITY

Lesson 7: Running Electrical Wiring

Name ______________________________

Date ______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. What wire size can be used if up to five two-wire circuits are being installed?

   a. AWG 8
   b. AWG 6
   c. AWG 4
   d. AWG 2

2. How many branch circuits are needed for small sheds with lighting?

   a. 2
   b. 3
   c. 4
   d. 5

3. At the yard pole, feeder wires carry power to the:

   a. Stack.
   b. Ground rod.
   c. Meter base.
   d. Neutral wire.

Complete the following short answer questions.

4. Why should lights, outlets, and switches be out of the reach of livestock in barns?

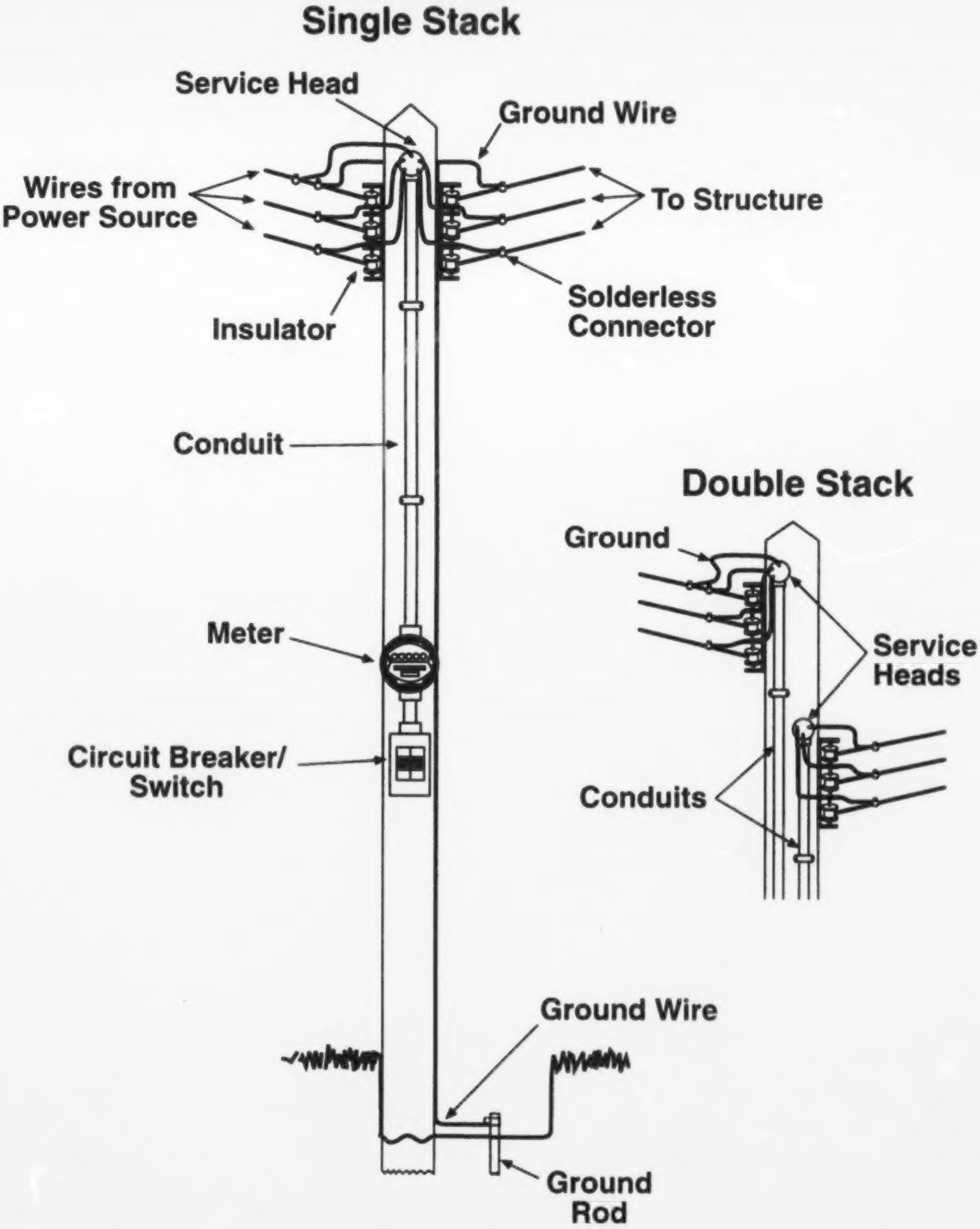
5. Why should hay dust be prevented from coming in contact with electrical sparks in hay barns?

6. Why are switches and receptacles designed for outdoor use useful in agricultural structures?

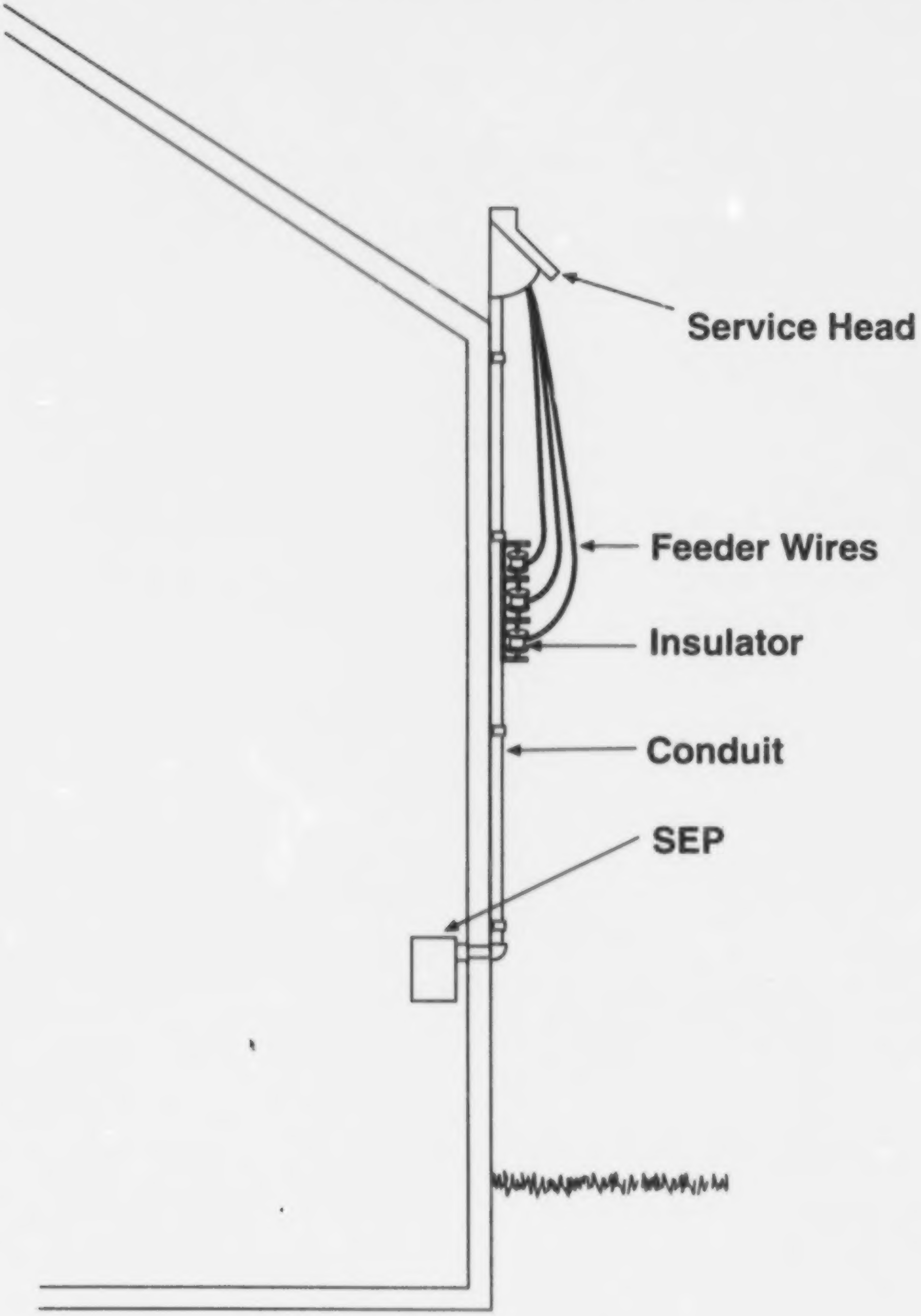
7. Where should the service entrance be installed?

8. What is the difference between a single stack and a double stack?

Wire Stacking at the Pole


Single Stack
Service Head
Ground Wire
Wires from Power Source
To Structure
Insulator
Solderless Connector
Conduit
Meter
Circuit Breaker/ Switch
Ground Wire
Ground Rod
Double Stack
Ground
Service Heads
Conduits

Installation of the Service Entrance


Service Head
Feeder Wires
Insulator
Conduit
SEP

Lesson 7: Running Electrical Wiring Name ______________________

Diagramming the Service Stack

Objective: Identify the stack configuration at the service pole or service entrance.

Identify the stack configuration found at either the electrical service pole or the service entrance at your home. In the space below, diagram the configuration. In the diagram, include the stack configuration, the meter base, the main disconnect switch (if present), and the wires. Color code the wires, using black or red for hot wires, grey for neutral wires, and green for ground wires.

UNIT V - ELECTRICITY

Lesson 8: Connecting to the SEP

Competency/Objective: Identify procedures for connecting the drop wires and branch circuit wires to the SEP.

Study Questions

1. **What are the parts of the SEP?**
2. **What are some good wiring practices to follow when wiring the panel?**
3. **What is the procedure for connecting the service entrance conductors to the SEP?**
4. **How is the ground system installed for the SEP?**
5. **How are circuit protectors selected and sized?**
6. **How are the 120-volt branch circuits connected to the SEP?**
7. **How are the 240-volt individual circuits connected to the SEP?**
8. **What is three-phase power, and when should its use be considered?**

References

1. *Agricultural Structures (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit V.
2. Transparency Masters
    a) TM 8.1: SEP Parts
    b) TM 8.2: Ground System
    c) TM 8.3: Wired 120/240 V Panel
3. Activity Sheet
    a) AS 8.1: Identifying SEP Components

Lesson 8: Connecting to the SEP

TEACHING PROCEDURES

A. ***Review***

Lesson 7 described bringing electrical power in at the yard pole and then installing wiring from the yard pole to the service entrance, after which wire can be run to branch circuits and electrical fixtures. The next step is making the connections at the service entrance panel. Within the SEP, circuits are linked to the power source, providing electrical power to the entire system.

B. ***Motivation***

Remove the cover from the SEP in the agriculture shop or building. Have students examine how the connections are made. Ask students if they can determine which circuits are 120 volts and which are 240 volts.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. The SEP distributes power throughout a structure. Ask students to list the components of an SEP. Use the SEP in the agriculture building to illustrate the different parts, or show students TM 8.1.

   What are the parts of the SEP?

   a) Cabinet - houses the parts of the SEP
   b) Main disconnect switch - large amperage breaker used to disconnect the power coming into the structure from the individual circuits
   c) Panel with banks, or rows, of sockets designed to accept either circuit breakers or fuses
   d) Circuit breakers or fuses - provide overcurrent protection for the circuits
   e) Neutral bar - specialized bar with terminal screws placed in it to make connections between neutral wires and ground wires
   f) Grounding screw - the point where the ground wire connects to the neutral bar
   g) Bonding strap - ground the cabinet

2. Describe proper wiring procedures at the SEP.

   What are some good wiring practices to follow when wiring the panel?

   a) Reducing overheating
      1) One way to reduce heat buildup is by wiring neatly and keeping wiring orderly within the cabinet.
      2) Keep wire runs in the SEP as straight and direct as possible.
      3) Wires should not be bent during wiring, because the constriction of wires can cause insulation damage as well as overheating.
   b) Other good practices
      1) Make tight connections without excessive bare wire showing at the terminal screws.
      2) Place the neutral bar in a convenient location in the SEP box to make direct wire runs easier.

3) Cut wires to the exact length necessary, removing any excess wire from the box.

3. Typically, three wires enter the SEP from the service drop, including two 120-volt hot conductors and one neutral conductor. Discuss the procedure for connecting the wires. Emphasize the importance of making secure connections.

What is the procedure for connecting the service entrance conductors to the SEP?

a) Check to make sure that the power is shut off.
b) Connect the two hot conductors to the main disconnect switch.
  1) Cut the conductors to the proper length.
  2) Strip off enough insulation to make a good connection.
  3) Insert the bare ends of the wire into the connectors on the main disconnect.
  4) Tighten the holding screws securely onto the wires.
c) Using the same procedures, attach the neutral wire to the neutral bar.
d) Ground the SEP cabinet by attaching either the flexible bonding strap or the ground wire to the grounding screw.

4. Discuss the installation of ground systems and grounding electrodes. TM 8.2 illustrates one type of ground system.

How is the ground system installed for the SEP?

a) Involves connecting a ground wire from the neutral bar in the SEP to a grounding electrode or a ground system
  1) Several different types of electrodes may make up ground systems.
    (a) Buried metal water pipe 10 feet or more in length, which must be supplemented by at least one other electrode
    (b) Grounded metal frame of the structure
    (c) Concrete-enclosed electrode
      (1) Composed of either 20 or more feet of ½-inch reinforced steel or AWG 4 copper wire
      (2) Placed inside at least 2 inches of concrete located near the bottom of the foundation and in direct contact with the earth
    (d) Buried AWG 2 or bigger wire that encircles the entire structure
  2) If none of these options for the ground system are available, a grounding electrode is used.
    (a) Underground metal piping or buried metal tanks
    (b) ½-inch copper rod or ⅝-inch metal or copper-clad rod
    (c) ¾-inch galvanized steel pipe
    (d) Buried metal plate at least 2 square feet in diameter
b) Size of the ground wire
  1) If the service entrance conductor is AWG 2 or smaller, AWG 6 or 8 wire should be used.
  2) If the service entrance conductor is AWG 1 or 0, AWG 6 is the minimum size permitted.
  3) If the service entrance conductor is AWG 2/0 or 3/0, the ground wire should be a minimum of AWG 4.
  4) If wire larger than AWG 3/0 is used at the service entrance, AWG 2 must be used for the ground connection.
c) Installation of the ground wire
  1) Fasten the wire to the surface over which it runs using special staples.
  2) Install the wire in a location that will minimize physical damage.
  3) Protection is typically provided by either tucking the grounding wire behind the service conduit entering the structure or running the wire along wall studs.
  4) If AWG 8 or smaller wire is used for grounding, protect it with a conduit.

5. Either circuit breakers or fuses are needed for overcurrent protection. Most structures being built have circuit breakers because they are easier to use. Discuss how circuit protectors are selected and sized.

   How are circuit protectors selected and sized?

   a) Determining whether fuses or circuit breakers will be used is important.
   b) Other factors considered when selecting overcurrent devices are the wire size and amperage ratings, the electrical devices operated on the circuit, and the demand load of the circuit.
   c) Correctly sized circuit protection devices must be installed.
      1) Main disconnect breaker
         (a) Determines the total electrical capacity of the SEP
         (b) Rated at 30, 40, 50, 60, 70, 90, 100, 125, 175, and 200 amps, with larger breakers available for industry purposes
      2) Fuses and circuit breakers
         (a) Begin at 15 amps and increase by 5-amp increments up to 50 amps.
         (b) Must have an amperage rating equal to or less than the rating for the conductor

6. Once the service wires have been connected into the SEP, the branch circuits can be connected. Describe the process of connecting 120-volt branch circuits. TM 8.3 can be used to illustrate the wiring.

   How are the 120-volt branch circuits connected to the SEP?

   a) Planning the location of each circuit before beginning the installation is important.
   b) Connect the neutral and ground circuit wires from the branch circuit to the neutral bar.
      1) Strip off enough insulation from the wires to make good contact with the neutral bar.
      2) Place each wire under a different screw on the neutral bar.
      3) Tighten the screws firmly.
   c) Attach the hot wire.
      1) Strip off the insulation of the black wire.
      2) Insert the wire under the terminal screw of the circuit breaker, which should be screwed tight.
   d) Insert the circuit breaker into the slot in the SEP panel.

7. Larger circuits that carry 240 volts use a double-pole circuit breaker for the connections at the SEP. Discuss how the circuits are connected, using TM 8.3 as an illustration. Hand out AS 8.1. To complete the activity sheet, contact a local electrician and obtain a SEP with breakers to use as a model. Wire the SEP as if it were actually in use. If possible, give the circuits sample labels, and ask students to identify their purpose.

   How are the 240-volt individual circuits connected to the SEP?

   a) Connect the black circuit wire to one terminal screw of the double-pole breaker.
   b) Connect the white circuit wire to the other terminal screw.
   c) Attach the ground wire to the neutral bar.

8. Another type of power that can be supplied to agricultural structures is three-phase power, which is a form of alternating current. Describe three-phase power and its uses.

   What is three-phase power, and when should its use be considered?

   a) Three-phase power

1) Three-phase AC power utilizes three hot wires, each carrying electrical current at different stages of alternation.
2) Each wire peaks in amperage at a slightly different point in time.
3) By synchronizing the wave patterns of the three hot wires, a more consistent amperage is achieved.

b) Uses
   1) Three-phase motors may be less expensive than single phase motors with the same horsepower.
   2) Three-phase power can also operate larger motors than standard single-phase power and will power those motors more efficiently.

c) Limiting factors
   1) The cost of three-phase power is higher than that for single-phase power.
   2) The power company must install additional transformers.
   3) A more expensive meter is needed to monitor power usage.

F. *Other Activities*

G. *Conclusion*

The service entrance panel provides power to all the circuits in an agricultural structure. The SEP houses individual circuit protection in the form of overcurrent devices and provides a centralized location for power control for the entire electrical system.

H. *Answers to Activity Sheet*

I. *Answers to Evaluation*

1. c
2. a
3. d
4. e
5. b
6. 30 amps or less
7. In a location that will minimize physical damage
8. To remove any excess wire from the box

9. Three-phase motors may be less expensive than single phase motors with the same horsepower, and three-phase power can also operate larger motors and will power those motors more efficiently.

10. Answers will vary, but the wires should be drawn and labeled appropriately.

UNIT V - ELECTRICITY

Lesson 8: Connecting to the SEP

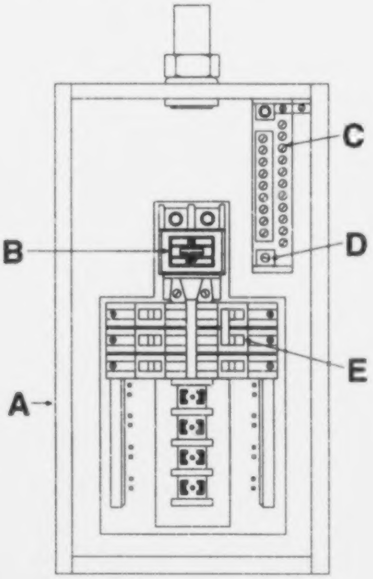
Name ______________________________

Date ______________________________

EVALUATION

Write the letter in the blank next to the name of the SEP part pictured.

1. ____ Main disconnect switch
2. ____ Circuit breaker
3. ____ Neutral bar
4. ____ Grounding screw
5. ____ Cabinet



Complete the following short answer questions.

6. If AWG 12 wire with a rating of 30 amps is used for a circuit, what size circuit breaker should be used?

7. Where should the ground wire be installed?

8. When wiring the SEP panel, why should wires be cut to the exact length necessary?

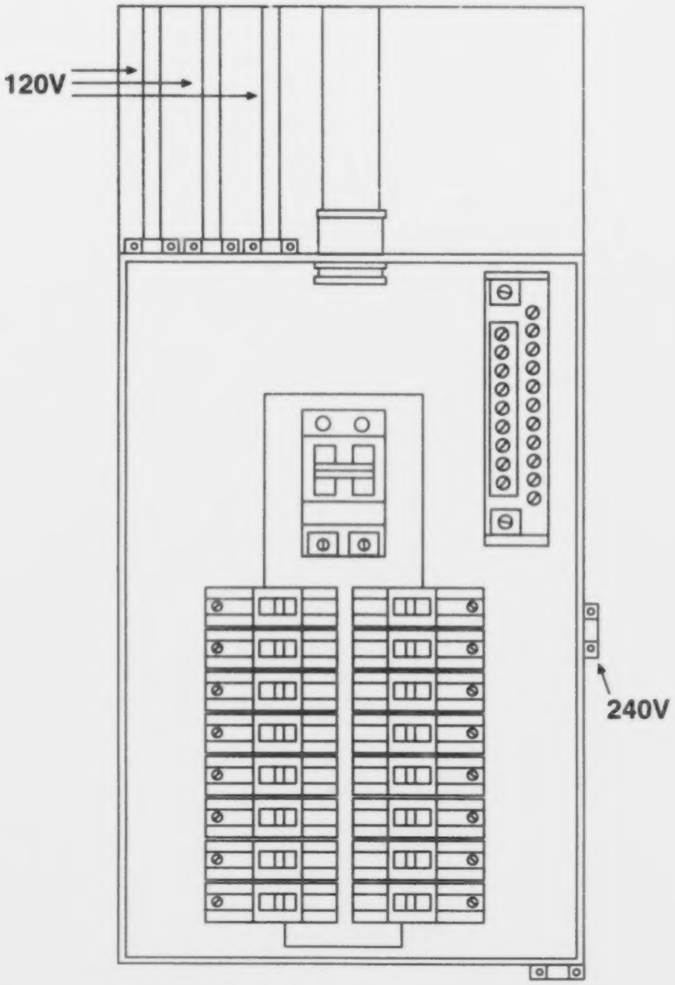
9. What are two reasons three-phase power might be used?

a.

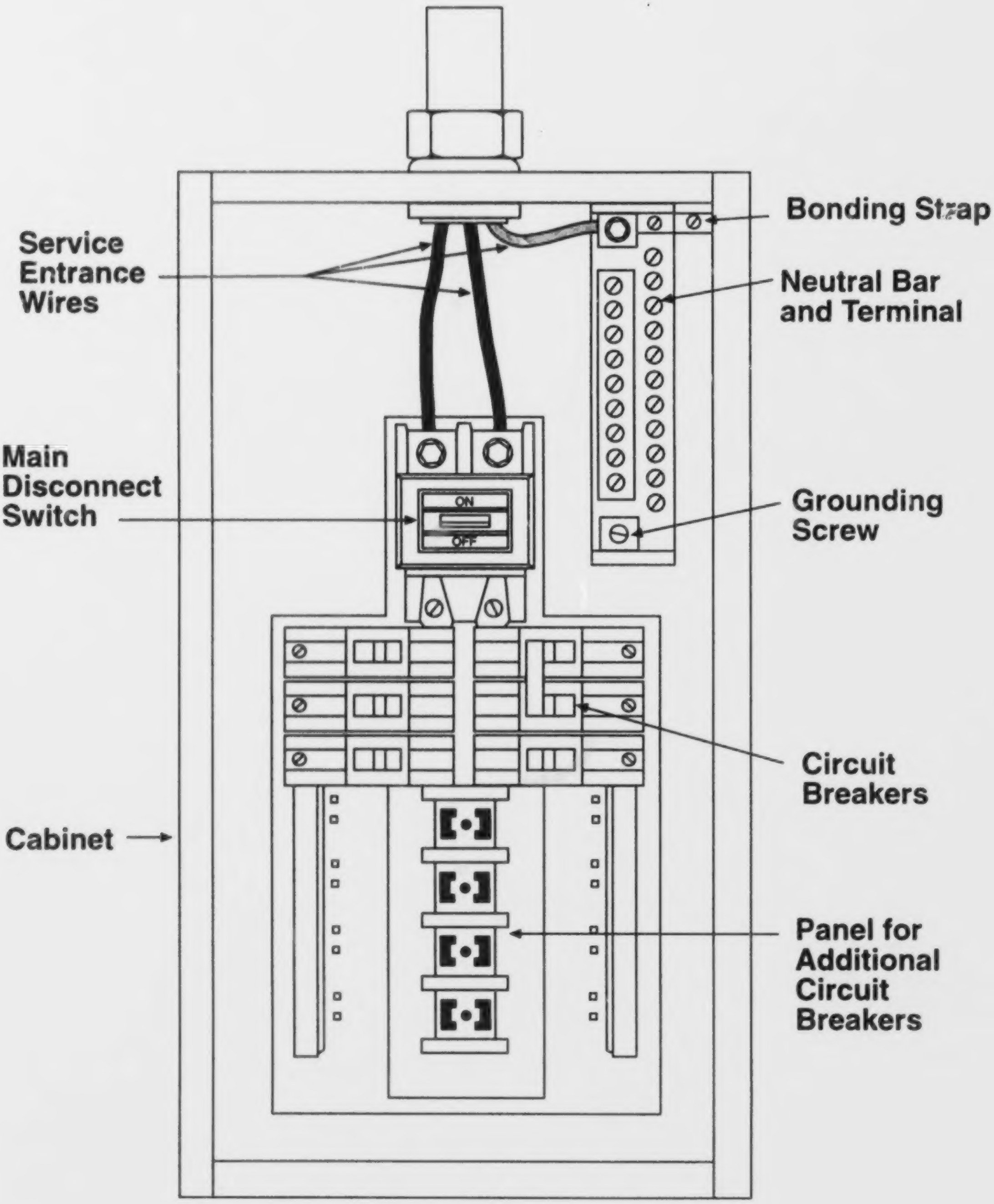
b.

On the diagram of the SEP, draw the wiring for the connections listed and label the conductors (hot, neutral, ground, etc.).

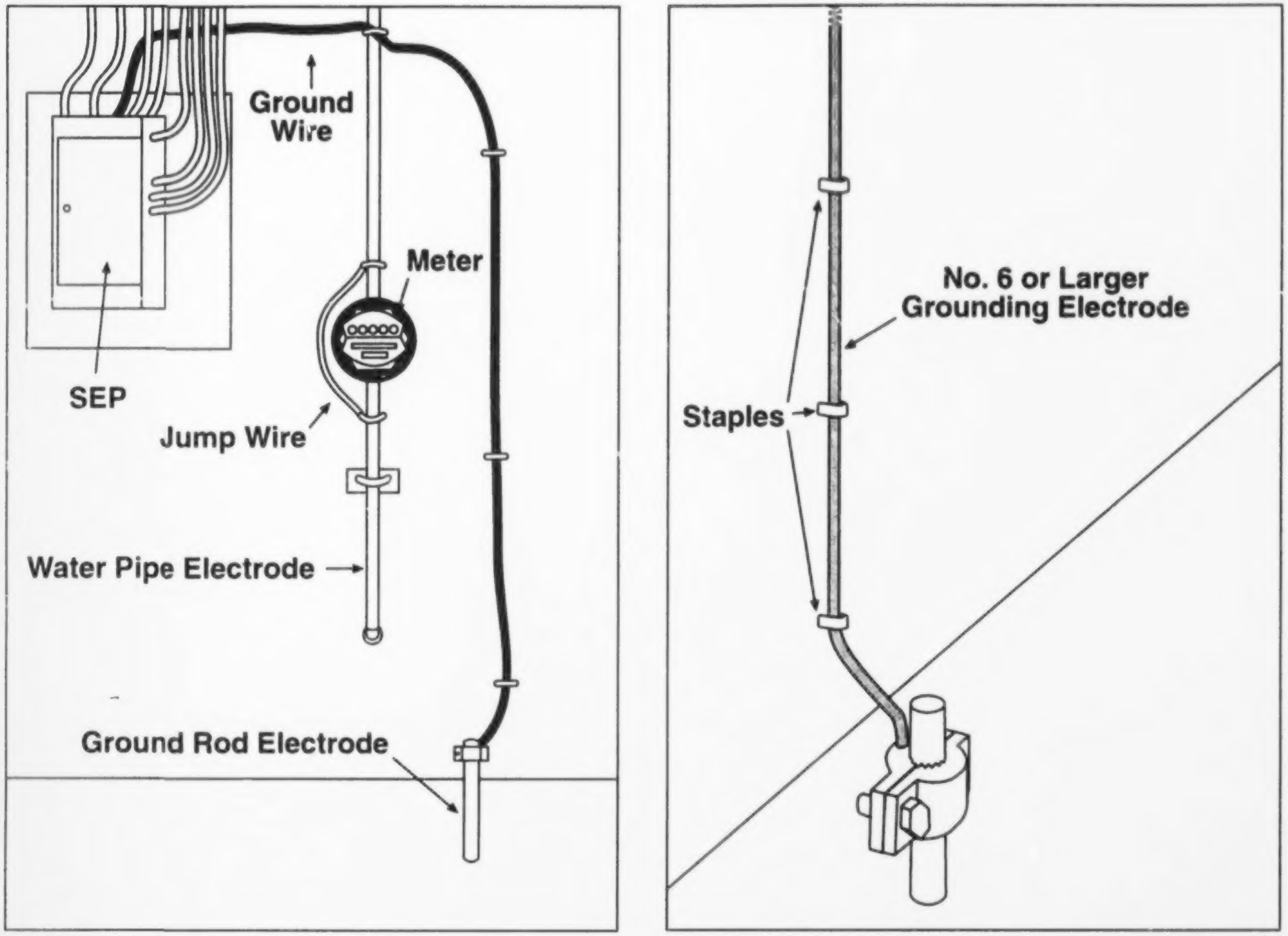
10.
- Service entrance conductors
- 120-volt branch circuit
- 240-volt branch circuit



SEP Parts


Bonding Strap
Service Entrance Wires
Neutral Bar and Terminal
Main Disconnect Switch
ON
OFF
Grounding Screw
Circuit Breakers
Cabinet
Panel for Additional Circuit Breakers

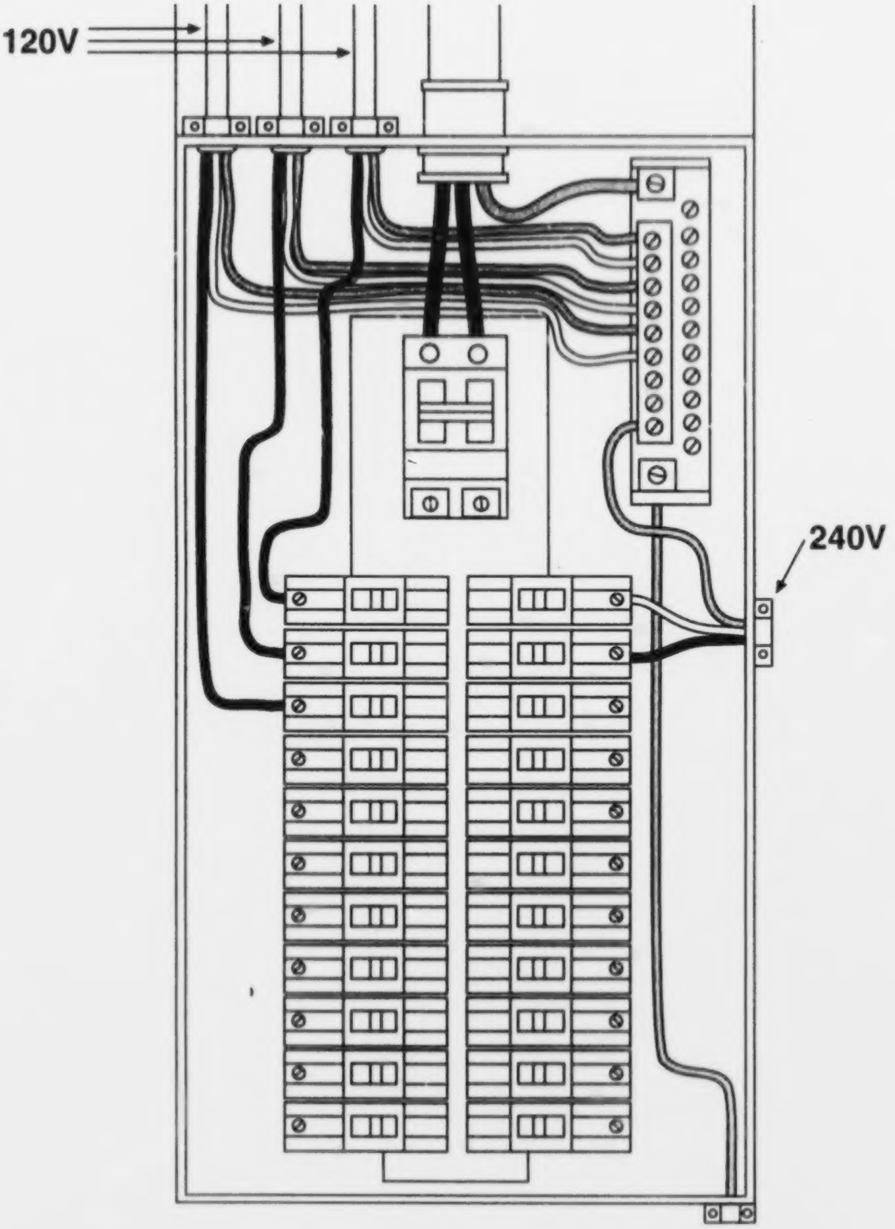
Ground System


Ground Wire
Meter
SEP
Jump Wire
Water Pipe Electrode
Ground Rod Electrode
No. 6 or Larger Grounding Electrode
Staples

Agricultural Structures, V-107

TM 8.2

Wired 120/240 V Panel



Agricultural Structures, V-109

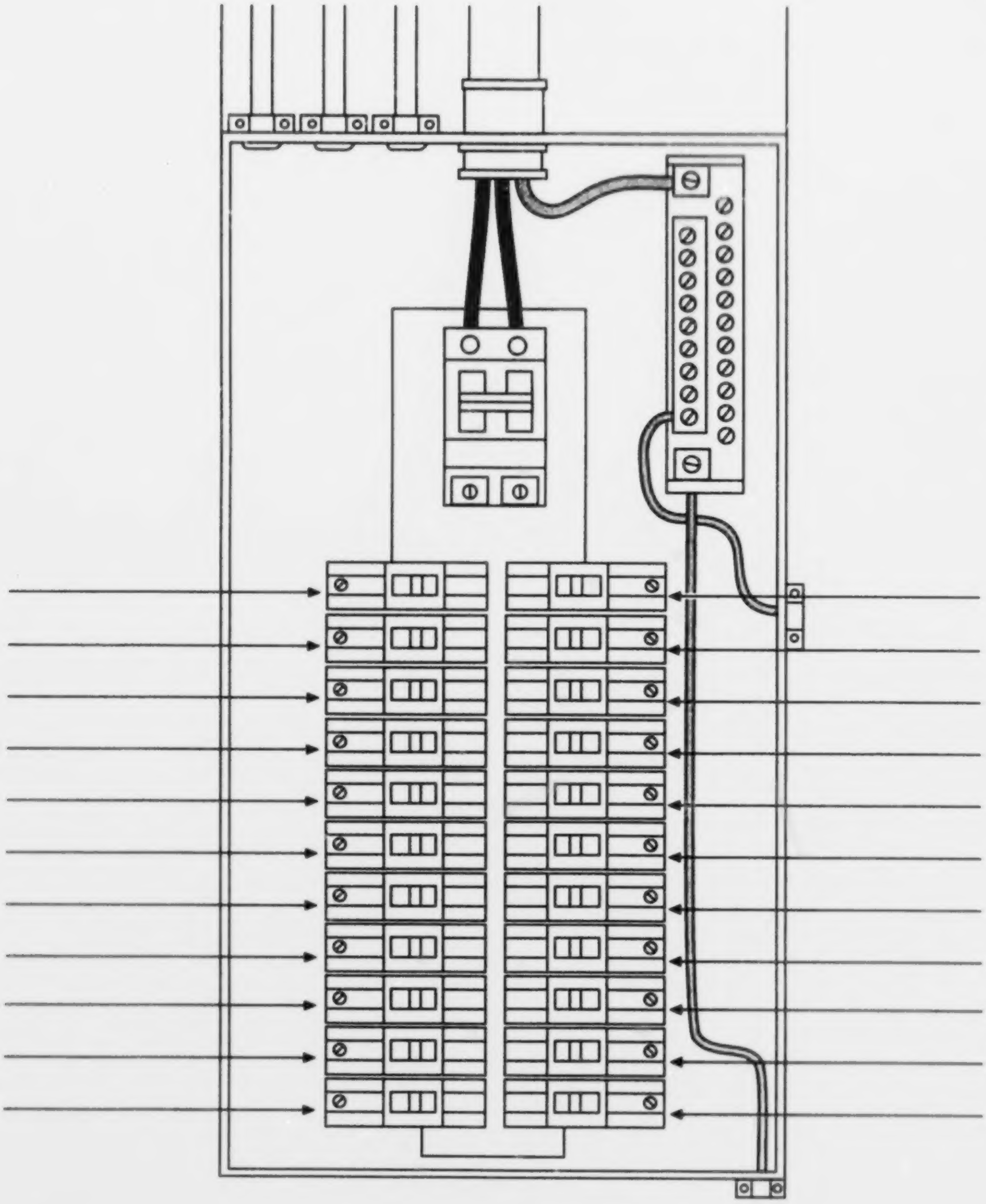
Lesson 8: Connecting to the SEP

Name ____________________

Identifying SEP Components

Objective: Identify the components of a service entrance panel.

Using the model SEP provided by your instructor, label the wires and breakers installed within the panel. List the amperage ratings of each breaker and whether the circuit is 120 volts or 240 volts.



UNIT V - ELECTRICITY

Lesson 9: Running Wire from the SEP

Competency/Objective: Describe how to run wiring from the SEP to a junction box, lights, and receptacles.

Study Questions

1. **Where should the service entrance panel be located?**
2. **How is the route of each circuit determined?**
3. **How are the wires run through the building?**
4. **What tools are needed to wire a receptacle or light?**
5. **What is the function of a junction box?**
6. **What techniques are used when splicing wires?**
7. **How is a light circuit wired?**
8. **How are convenience outlet circuits wired?**

References

1. *Agricultural Structures* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit V.

3. Transparency Masters

    a) TM 9.1: Wiring Diagram
    c) TM 9.2: Labeling Receptacles
    d) TM 9.3: Ceiling Runs
    e) TM 9.4: Wall Runs
    f) TM 9.5: Junction Box
    g) TM 9.6: Connectors
    h) TM 9.7: Wiring a Switch and Light
    I) TM 9.8: Wiring a Switch Loop
    j) TM 9.9: Wiring a Three-Way Switch and Light
    j) TM 9.10: Series and Parallel Wiring
    k) TM 9.11: Wiring a Convenience Outlet

3. Job Sheet

    a) JS 9.1: Wiring a Three-Way Switch

UNIT V - ELECTRICITY

Lesson 9: Running Wire from the SEP

TEACHING PROCEDURES

A. ***Review***

Lesson 8 described the proper methods for making connections at the service entrance panel. Lesson 9 will examine how branch circuits are planned and how wire is run through a structure. Switches, lights, and convenience outlets can then be installed.

B. ***Motivation***

Show the students examples of light fixtures and convenience outlets so they can see the terminals used in wiring. Display the tools used in installing the different devices.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Ask students where the SEP should be located within an agricultural structure. Discuss the factors that affect its location.

   Where should the service entrance panel be located?

   a) As close as practical to the point where the wires enter the building
   b) Near equipment that has a high electrical draw, such as water heaters or large motorized equipment
   c) In an easily accessible location
      1) In an emergency, someone must be able to shut off power immediately.
      2) Ease of access to the panel is necessary if fuses blow or breakers are tripped.
      3) An easily accessible panel makes it easier to add circuits to the system.

2. Because a number of different circuits may control different outlets, lights, and equipment, the path of each electrical circuit should be carefully planned. Discuss the use of wiring diagrams; a sample diagram is provided in TM 9.1. Describe how circuits and electrical devices can be labeled to distinguish between them, as shown in TM 9.2.

   How is the route of each circuit determined?

   a) Two types of electrical circuits are considered when making a wiring plan.
      1) General circuits - circuits carrying 110-volt current and normally containing more than one electrical device
      2) Individual circuits - circuits carrying 220 volts of current and typically operate a single piece of equipment
   b) The next consideration is which outlets will be connected to which circuit at the service entrance panel.
      1) A good rule of thumb is to avoid placing all the light fixtures in the same room or building on one circuit.
      2) The amount of electrical load placed on convenience outlets will determine their circuit needs.
         (a) On a single circuit if the outlets in a room or building will have low usage, with one to two outlets used at any given time

        - (b) On different circuits if more than two outlets will be used at once or equipment with a high electrical draw will be used on a regular basis
  - c) A wiring diagram is useful when planning where branch circuits will run and what electrical devices will be connected to them.
    - 1) Mark the entry point.
    - 2) Add up the number of devices on the circuit and make sure sufficient amperage can be supplied.
    - 3) Repeat this process for each circuit.
  - d) Physically mount outlet boxes for lights and receptacles at each location, and label them on the diagram and within the structure for easy reference.
    - 1) Use Roman numerals for the individual circuit line.
    - 2) Letters designate the different outlet boxes.
    - 3) Switches are labeled with an S.
    - 4) Three-way switches are labeled S1 and S2.

3. Describe the techniques used when running wires through a structure. TMs 9.3 and 9.4 illustrate ceiling and wall wire runs.

   How are the wires run through the building?

   - a) Wire protection
     - 1) Avoid excessive bending of electrical conductors to prevent the insulation from cracking.
     - 2) Run wire inside of walls and ceilings to prevent physical damage.
     - 3) Exposed wire runs or runs where damage may be a concern should have the conductor placed inside of a conduit.
   - b) General practices
     - 1) Conductors should run as straight as possible from the SEP to the individual outlets.
     - 2) As few splices as possible should be used.
     - 3) Wire runs should be as high and dry as possible.
   - c) Ceiling runs
     - 1) Ceiling runs are best because damage from traffic is minimized.
     - 2) They reduce wire damage because the wires are not located where water may collect or flow.
   - d) Floor runs - Noncorrosive conduits should enclose the wires.
   - e) Wall runs
     - 1) Drill a hole in the center of the wall studs that is large enough to accept the conduit or to allow the cable to slide through easily without friction and binding.
     - 2) Staple the wire along the side of a stud.
     - 3) Cut a notch in the side of the wall studs, and install a steel cover plate over the notch after the wire is in place.
     - 4) In structures where moisture will not be a factor, notch the bottom of the studs and run the wires along the bottom plate of the wall.

4. The use of the proper tools is essential to installing wiring efficiently and safely. Ask students to list the tools that they would use in wiring a light fixture or convenience outlet.

   What tools are needed to wire a receptacle or light?

   - a) Essential tools
     - 1) Wire cutters, either lineman's pliers, side cutting pliers, or needlenose pliers
     - 2) Cable rippers, which is used to remove the cable covering from the conductors housed in the cable sheathing
     - 3) Wire strippers for removing insulation from conductors
     - 4) Complete set of screw drivers
     - 5) Hammer
     - 6) Slip-joint pliers

      7) Level
      8) Tubing cutter for cutting conduit
      9) Conduit bender, which is used to bend or form conduit to turn corners
   b) Other tools
      1) Socket wrenches
      2) Drill motor and drill bits
      3) Adjustable open-end wrench
      4) Hand saw
      5) Electrical testing equipment

5. Sometimes branching a circuit is necessary. Discuss the use of junction boxes. TM 9.5 shows wiring within a junction box.

   What is the function of a junction box?

   a) Used to protect the wires that are spliced together to branch circuits - Junctions are sometimes needed if a long electrical run is required or if no convenient outlets are available from which to branch power to different outlets on the same circuit.
   b) Basically an outlet box with a solid cover
      1) The NEC states that all boxes must be dust tight and watertight.
      2) The NEC also requires that they be made of corrosion-resistant material.
      3) Junction boxes should be located where they are permanently accessible for repairs.
   c) Connections in a junction box
      1) Insert the ends of the wires into the junction box through the knockouts.
      2) About 6 inches of each wire should pass through the knockouts.
      3) Connect black wires to black wires, white wires to white wires, and ground wires to ground wires.
      4) If the outlet box is metal, connect a separate piece of wire to the box and the ground wires.
      5) Clamp the wires securely to the box to prevent the splices from pulling apart.

6. Splices should be as sound as an unbroken conductor. Describe the different types of connectors that may be used. Different types of solderless connectors are shown in TM 9.6.

   What techniques are used when splicing wires?

   a) Insulated solderless connectors (wire nuts)
      1) Strip back the wire insulation just enough for the wires to fit inside the connector.
      2) Lay the wires together.
      3) The method for connecting the wires depends on the connector selected.
         (a) Threaded metal insert - Screw the connector onto the wires to be joined.
         (b) Removable metal insert
            (1) Remove the insert from the insulating shell.
            (2) Slip the insert over the wires.
            (3) Tighten the set screw in the insert to lock the wires in place.
            (4) Screw the insulating shell back on over the insert.
         (c) Spring-loaded - Screw the connector onto the wires to be spliced.
      4) Tape the conductors if necessary.
   b) Metal connectors for wires that are AWG 8 and larger
      1) They have a collar with a set screw.
      2) Insert the wires into the connector.
      3) Tighten the screw.
      4) Wrap the connector and wires with electrician's tape.

7. Because most structures have some form of lighting, understanding how to wire lights and switches is important. Describe how different types of circuits should be wired. TMs 9.7, 9.8, and 9.9 show the wiring for a switched circuit, switch loop, and three-way switch. TM 9.10 can be

used to illustrate series and parallel wiring. Hand out JS 9.1. The mock walls that students will use for wiring should be prepared before class period. They are made using 2" × 4" boards and should measure 2 feet by 2 feet.

How is a light circuit wired?

a) Simple circuit
    1) Connect the black hot wire to a brass screw on the light fixture.
    2) Connect the white neutral wire to a silver screw.
    3) This system is impractical because the light cannot be turned on and off.
b) Switched circuit
    1) A switch breaks the electrical circuit of the light fixture.
    2) White, black, and ground wires enter the switch box from the power source.
        (a) Connect the white source wire to a white wire with a connector.
        (b) Connect the black source wire to a brass screw on the switch.
        (c) Attach a black wire to the other screw on the switch.
        (d) At the light fixture, connect the black wire to a brass screw and the white wire to a silver screw.
        (e) Connect a green ground wire from the light fixture to the ground wire from the source using a solderless connector.
        (f) If the boxes are metallic, the ground wires are attached to the boxes with a piece of wire.
    3) In a switch loop, a pair of black wires brings the power to the switch from the lighting box and carries it back to the light.
        (a) Connect the black source wire to a length of black wire with a connector.
        (b) Connect this wire to a brass screw on the switch.
        (c) Connect another black wire to the other brass screw on the switch.
        (d) This second black wire runs back to the lighting box.
        (e) Attach it using a connector to a black wire from the brass screw on the fixture.
        (f) Connect the white source wire to a white wire from the light fixture using a connector.
        (g) Attach the white wire to a silver screw at the light fixture.
c) Three-way switch
    1) Using a three-way switch, a light can be turned off and on from two different locations.
    2) Wiring a three-way switch begins at one of the switches.
        (a) Connect the black wire from the power source to the common terminal on the switch.
        (b) Connect a black wire to the switch on the opposite side from the black source wire.
        (c) Connect a red wire to the other terminal on that side.
        (d) Splice the white wire from the source to another white wire with a solderless connector.
        (e) Make the appropriate ground connections at the switch.
    3) Next, the other wires are connected at the second switch.
        (a) Connect a black wire to the common terminal of the switch.
        (b) Attach a red wire to the terminal opposite the black wire.
        (c) Connect a white wire to the other terminal.
        (d) Make the ground connections in the box.
    4) The wires from the two switches meet at the light fixture.
        (a) Connect the black wire from the first switch to the white wire from the second switch using a solderless connector.
        (b) Splice the red wires together using a connector.
        (c) Attach the black wire from the second switch to the brass screw on the fixture.
        (d) Connect the spliced white wire from the power source to the silver screw.
d) Series and parallel wiring - Used when more than one light fixture is on a circuit

        1) Series wiring is an impractical system because the way the outlets are connected, if one light goes out, they all go out.
            (a) The black wire from the source is attached to a terminal on the first fixture.
            (b) A white wire then runs directly from the second terminal to the next lighting fixture and attaches to a terminal there.
            (c) Another black wire runs from the second terminal on that fixture directly to the next fixture.
            (d) This pattern continues through the series.
        2) Parallel wiring is the most common method of wiring multiple light fixtures.
            (a) Jumper wires attached to each light fixture are spliced to the white and black wires from the power source.
            (b) This system allows power to flow separately to each individual lamp on the same circuit.

8. Describe the process for wiring a circuit with one receptacle or several receptacles. TM 9.11 can be used to illustrate the wiring.

    How are convenience outlet circuits wired?

    a) One receptacle
        1) Attach the black source wire to the side of the receptacle with the brass screw.
        2) Attach the white wire to the silver screw on the opposite side of the receptacle.
        3) Join the ground wires using a connector.
    b) Two or more receptacles on a circuit
        1) Connect the first receptacle as described.
        2) Connect another black wire to the other brass screw on the first outlet and to the brass screw on the second receptacle.
        3) Connect a white wire to the second silver screw on the first receptacle and the silver screw on the second.
        4) Follow the same procedure for any other receptacles on the same circuit.
        5) Make the appropriate ground connections.

F. *Other Activities*

Have students draw a diagram on a piece of paper showing how to hook a series of outlet receptacles to an on/off switch at the source. They should color code the different wires used.

G. *Conclusion*

The location of the circuits within an agricultural structure should be planned before running any wire to make sure that it is installed correctly. Once the wire is in place, light fixtures and convenience outlets can be installed.

H. *Answers to Activity Sheets*

I. *Answers to Evaluation*

1. c
2. a
3. e
4. d
5. b
6. b
7. d
8. d
9. a

10. Jumper wires attached to each light fixture are spliced to the white and black wires from the power source.

11. Threaded metal insert connector, removable metal insert connector, and spring-loaded connector
12. A wiring diagram

13. Answers may include any two of the following: drilling a hole in the center of the wall studs, stapling the wire along the side of a stud, cutting a notch in the wall studs and covering it with a steel plate, and cutting a notch in the bottom of the studs and running the wires along the bottom plate of the wall.

14. To protect the wires that are spliced together to branch circuits

UNIT V - ELECTRICITY Name ____________________________

Lesson 9: Running Wire from the SEP Date ____________________________

EVALUATION

Match the tools on the right with the description on the left.

1. ______ Used to cut conduit
2. ______ May use lineman's pliers
3. ______ Used to form conduit
4. ______ Used to remove insulation
5. ______ Used to remove cable covering

a. Wire cutters
b. Cable ripper
c. Tubing cutter
d. Wire stripper
e. Conduit bender

Circle the letter that corresponds to the best answer.

6. Which of the following is used to indicate the circuit line in a label?

   a. Arabic numerals (1, 2, 3, etc.)
   b. Roman numerals (I, II, III, etc.)
   c. Letters (A, B, C, etc.)
   d. Special symbols (S1, S2, S3, etc.)

7. Where should the service entrance panel be located?

   a. In the basement of a structure
   b. Near the point where the circuits come together
   c. In a corner of the building
   d. Near where the wires enter the building

8. When wiring a single receptacle, the __________________ is attached to the brass screw.

   a. White source wire
   b. Green ground wire
   c. Red hot wire
   d. Black source wire

9. At a light fixture, the __________________________ is attached to the silver screw.

   a. White wire
   b. Green wire
   c. Red wire
   d. Black wire

Complete the following short answer questions.

10. How are light fixtures wired in parallel wiring?

11. What are three types of solderless connectors?

    a.

    b.

    c.

12. What can be used to help plan the path of branch circuits?

13. What are two ways wire may be run in walls?

    a.

    b.

14. What is a junction box used for?

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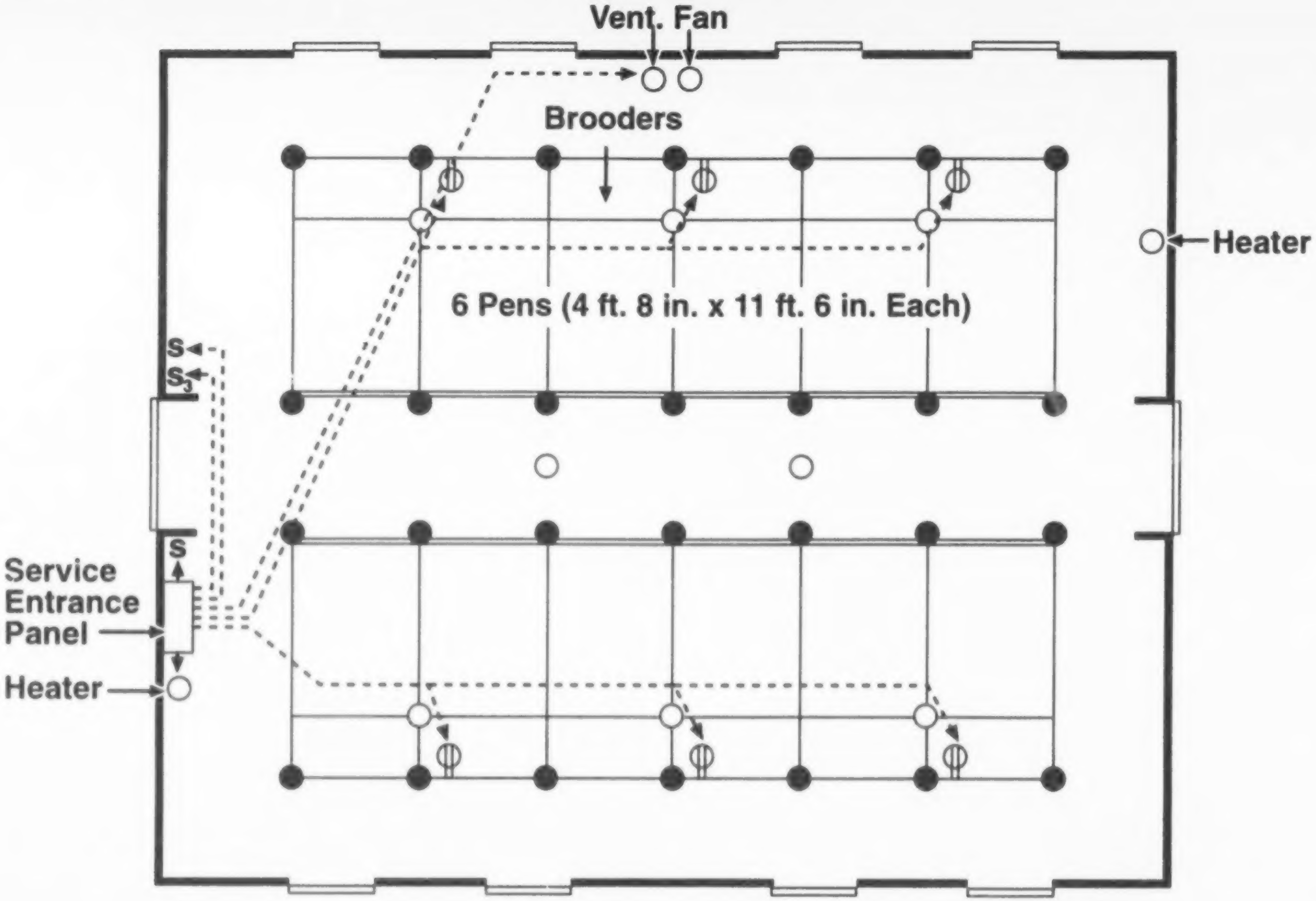
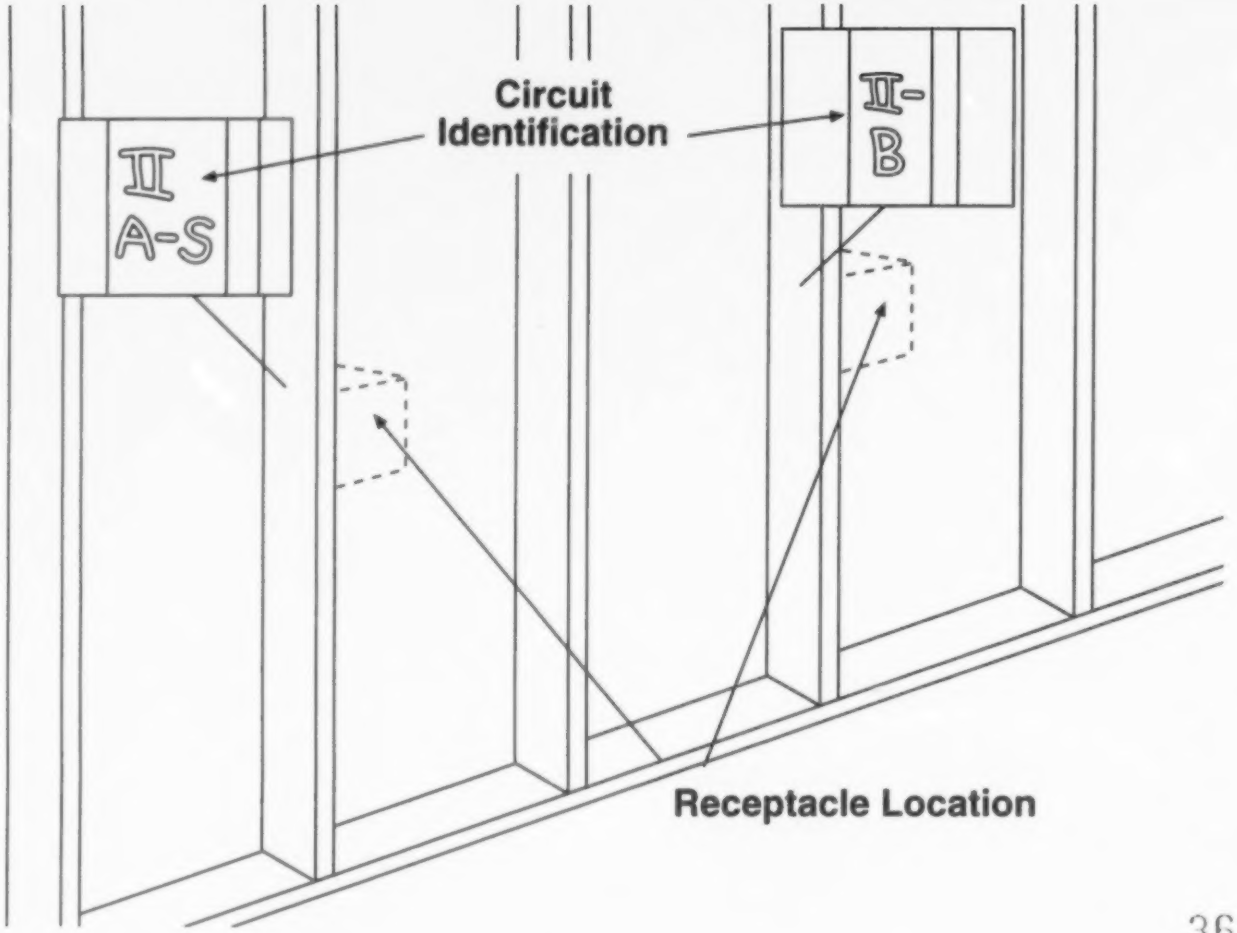
Wiring Diagram


Vent. Fan
Brooders
Heater
6 Pens (4 ft. 8 in. x 11 ft. 6 in. Each)
S
S_3
S
Service Entrance Panel
Heater

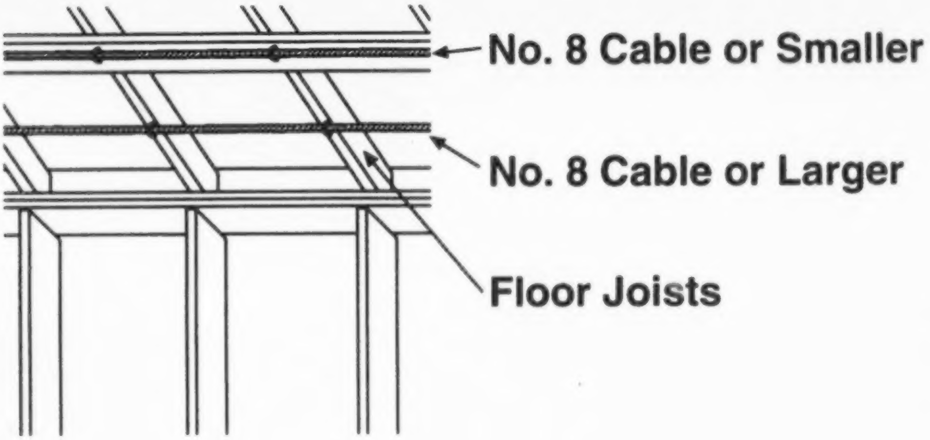
12-Pen Hog Farrowing House

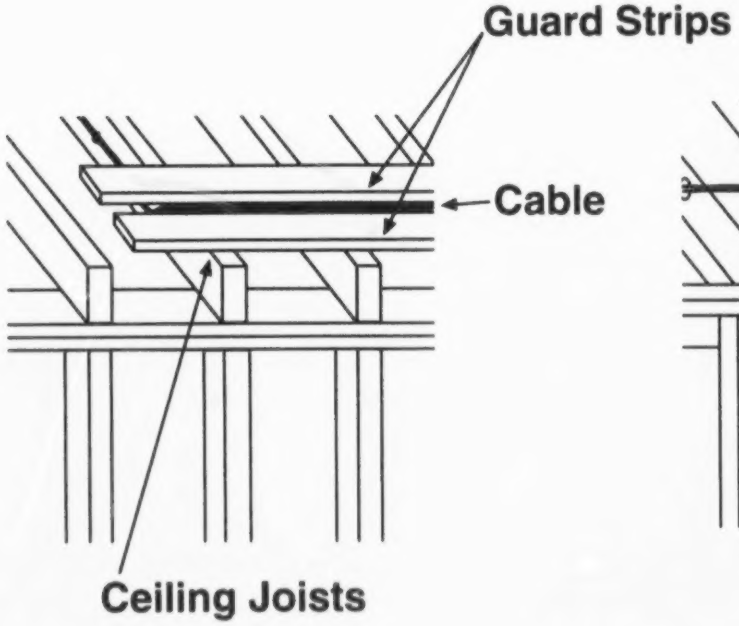
Labeling Receptacles

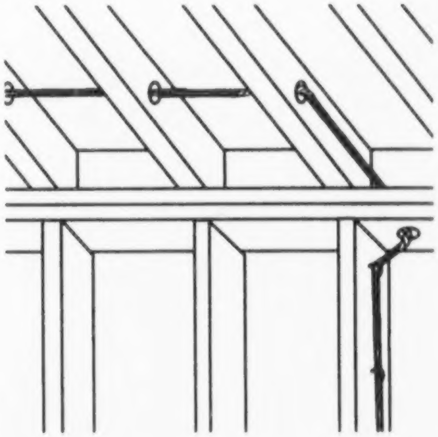

Circuit Identification
II A-S
II-B
Receptacle Location

TM 9.3

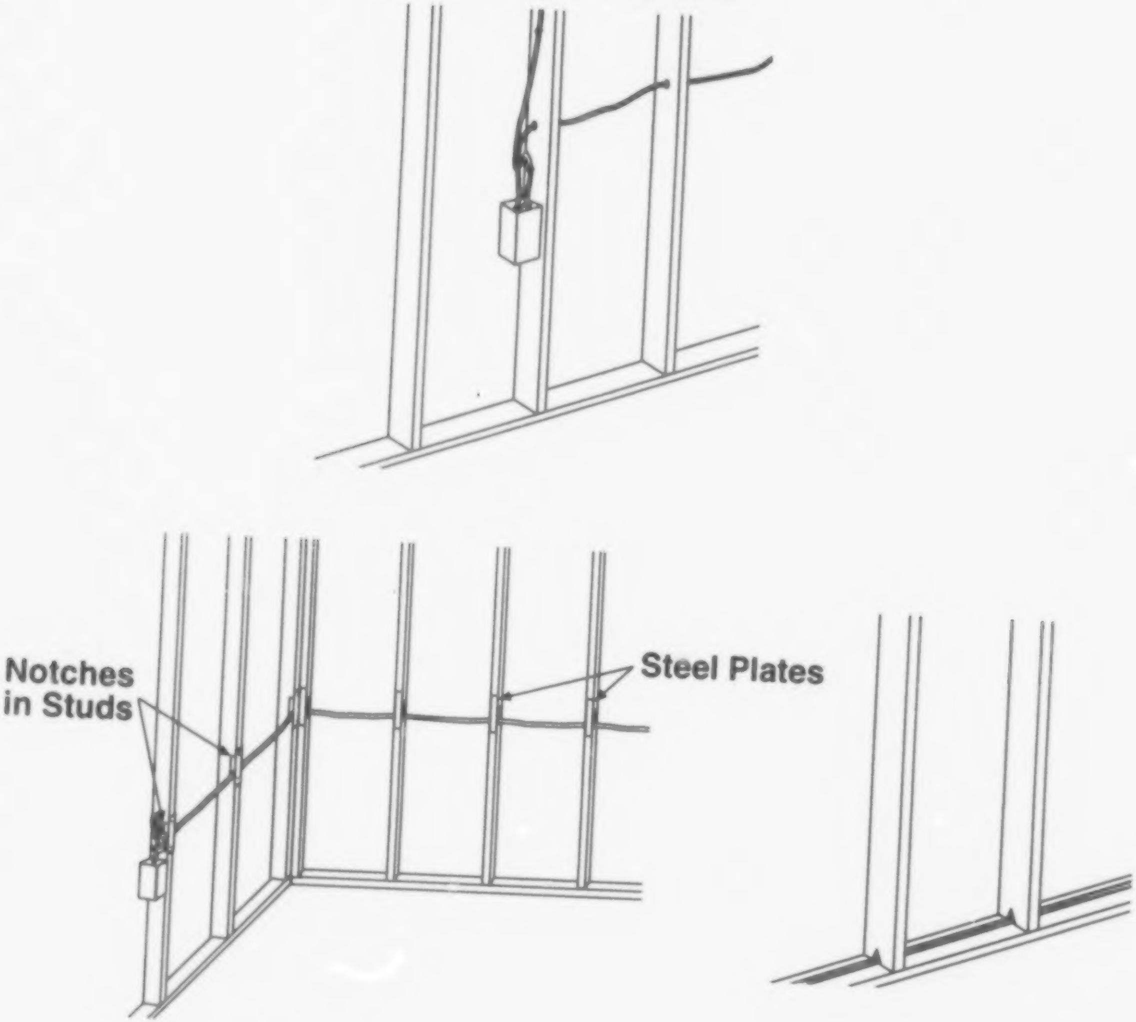
Ceiling Runs


No. 8 Cable or Smaller
No. 8 Cable or Larger
Floor Joists

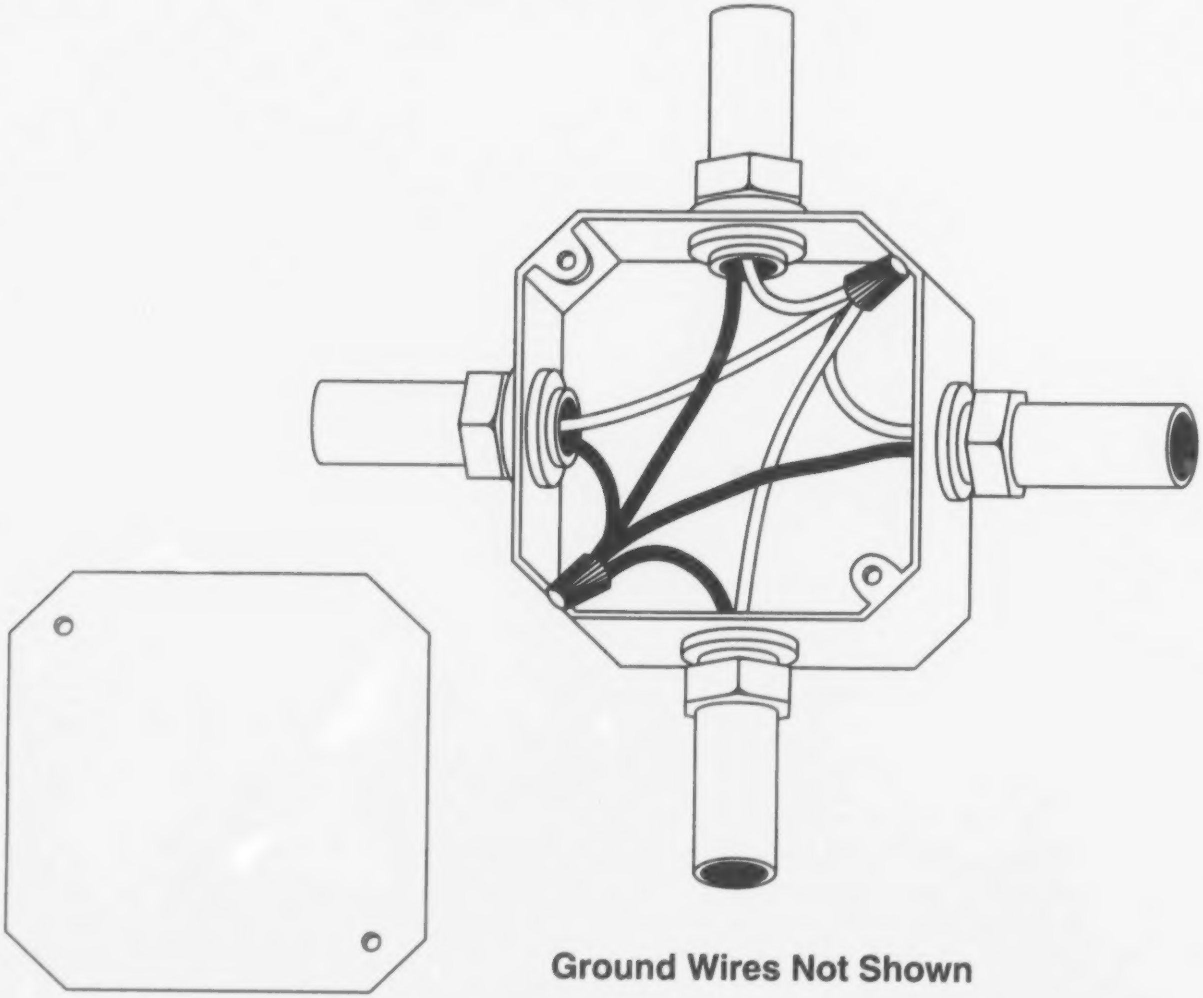

Guard Strips
Cable
Ceiling Joists



Wall Runs

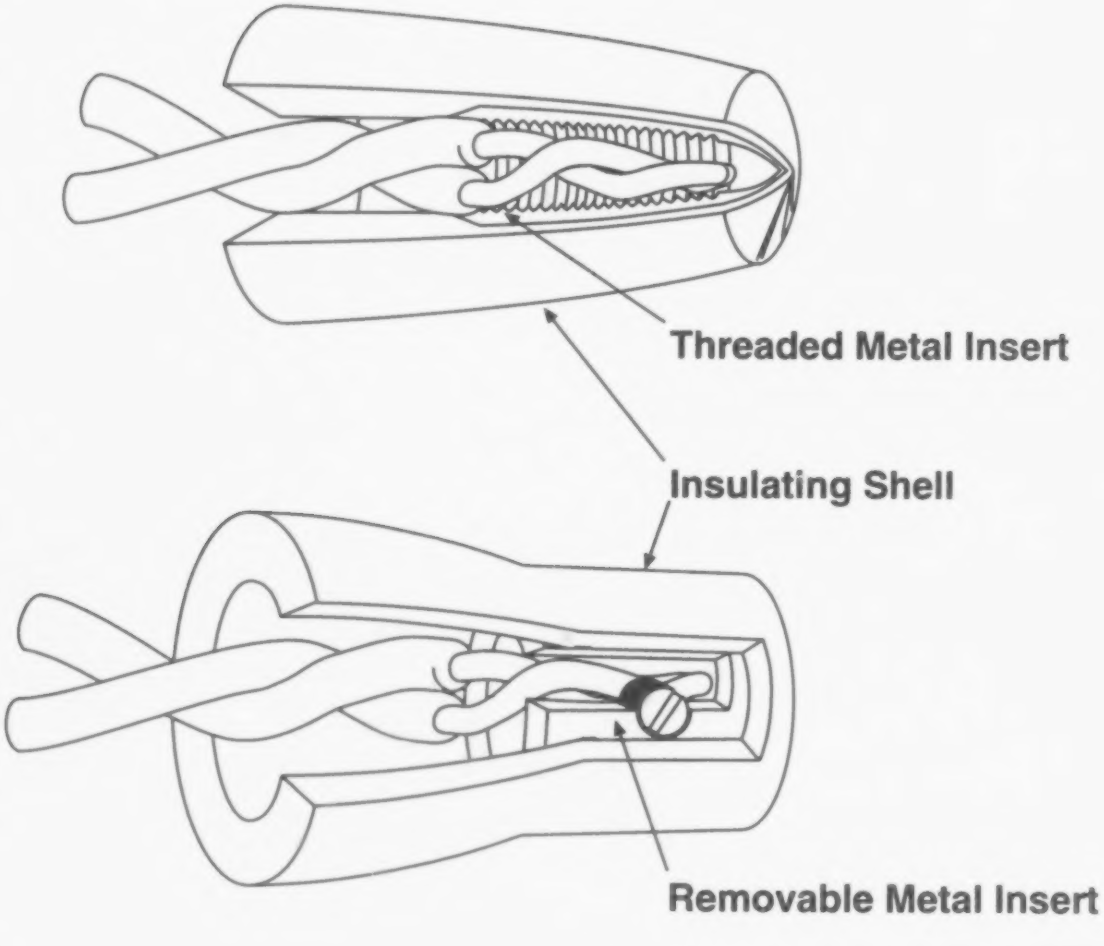

Notches in Studs
Steel Plates

Junction Box

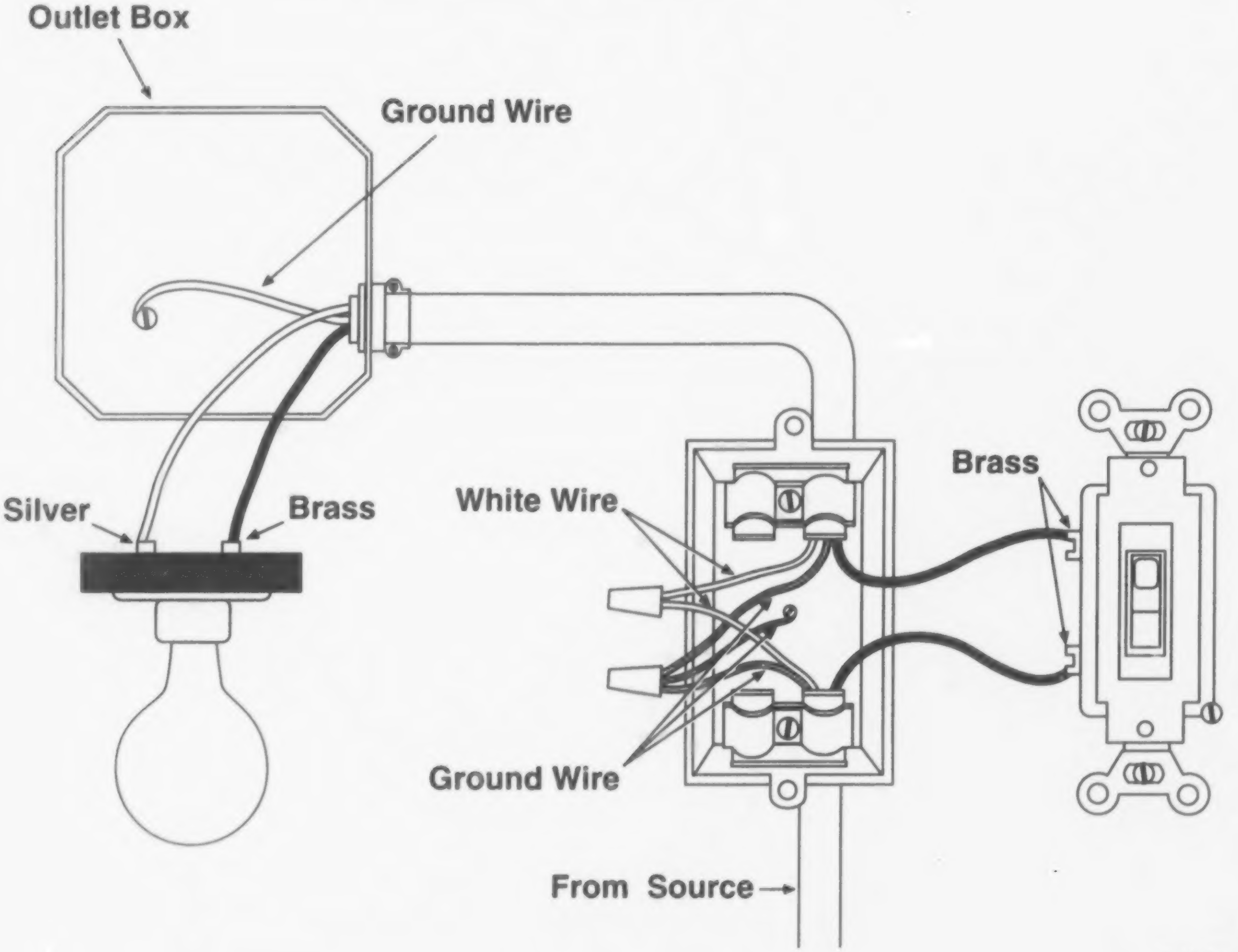


Ground Wires Not Shown

Connectors


Threaded Metal Insert
Insulating Shell
Removable Metal Insert

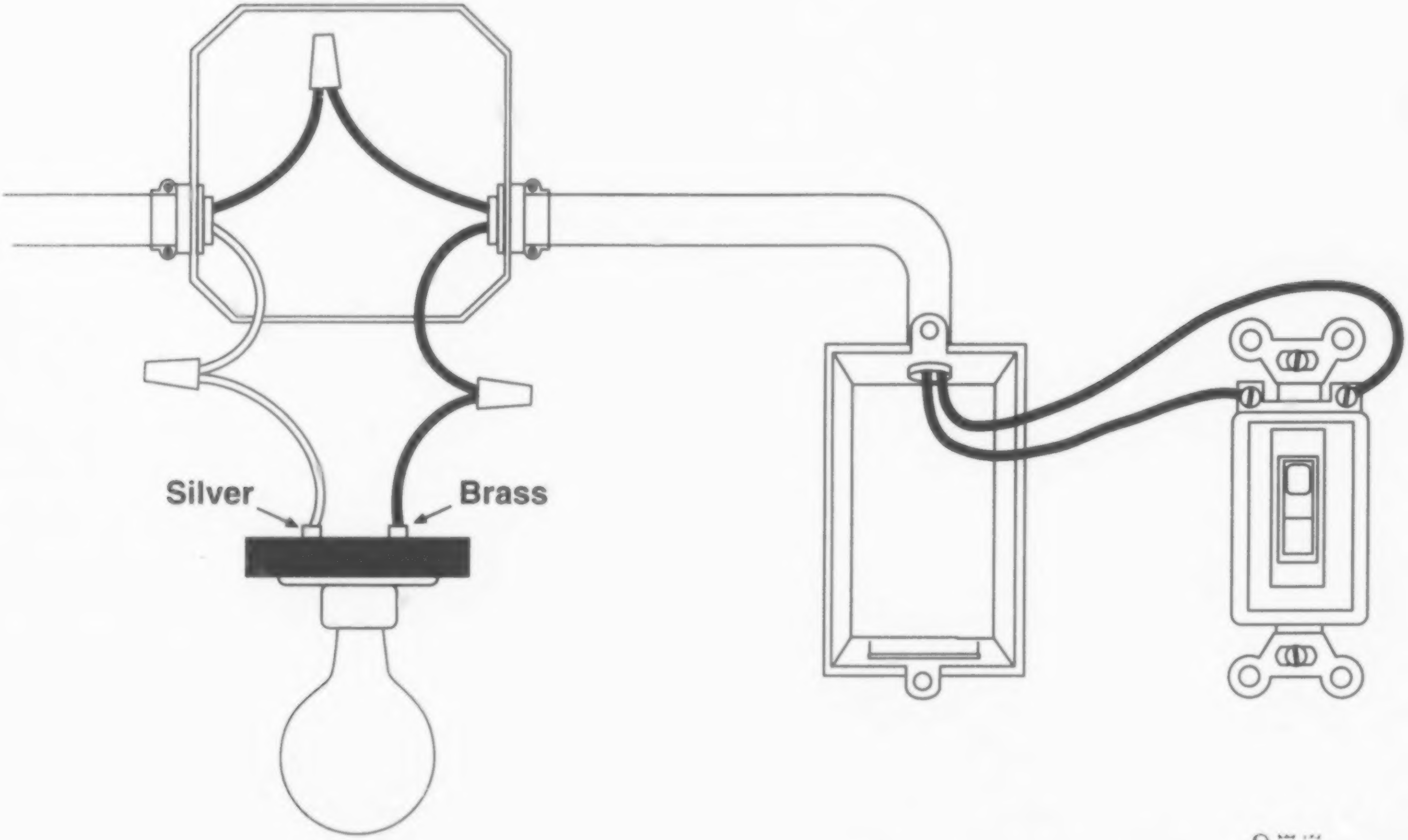
Wiring a Switch and Light


Outlet Box
Ground Wire
Silver
Brass
White Wire
Brass
Ground Wire
From Source

Agricultural Structures, V-135

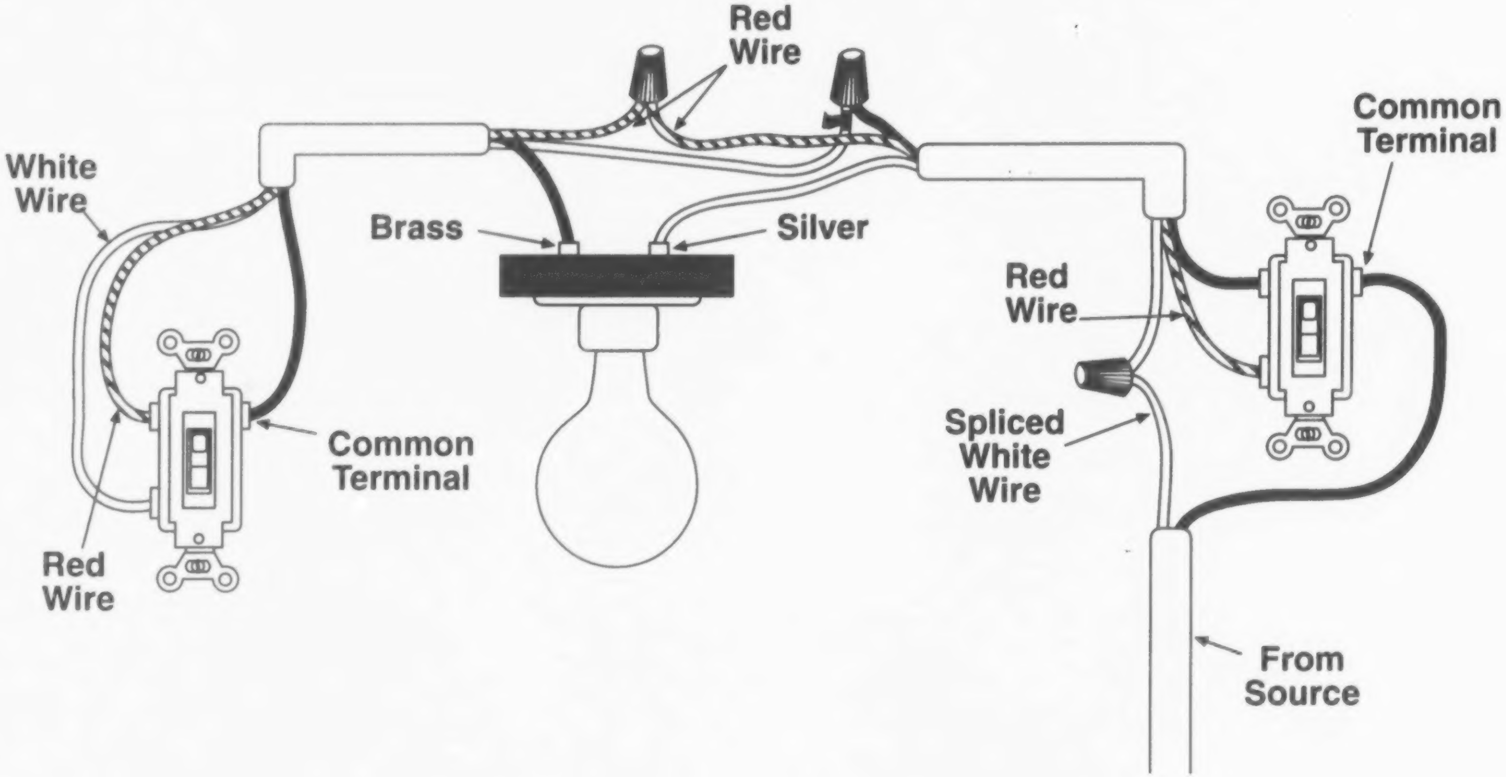
TM 9.7

Wiring a Switch Loop


Silver
Brass

Agricultural Structures, V-137

Wiring a Three-Way Switch and Light


Red Wire
Common Terminal
White Wire
Brass
Silver
Red Wire
Spliced White Wire
Common Terminal
Red Wire
From Source

Agricultural Structures, V-139

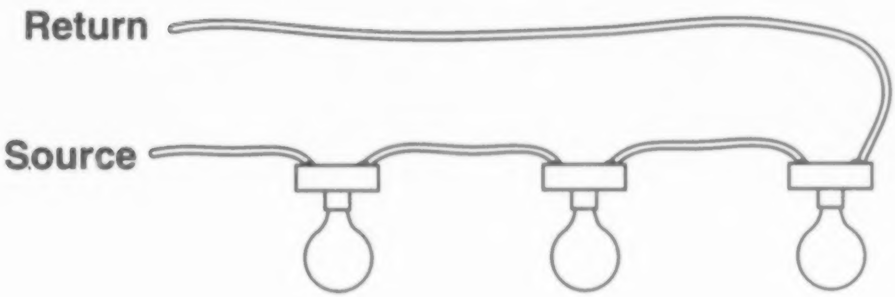
Note: Ground wire and boxes not shown.

TM 9.9

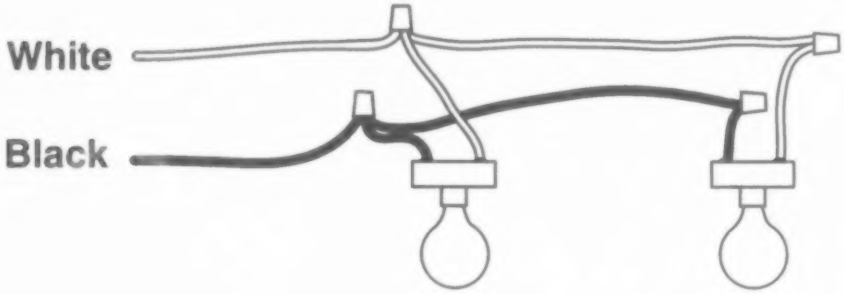
TM 9.10

Series and Parallel Wiring

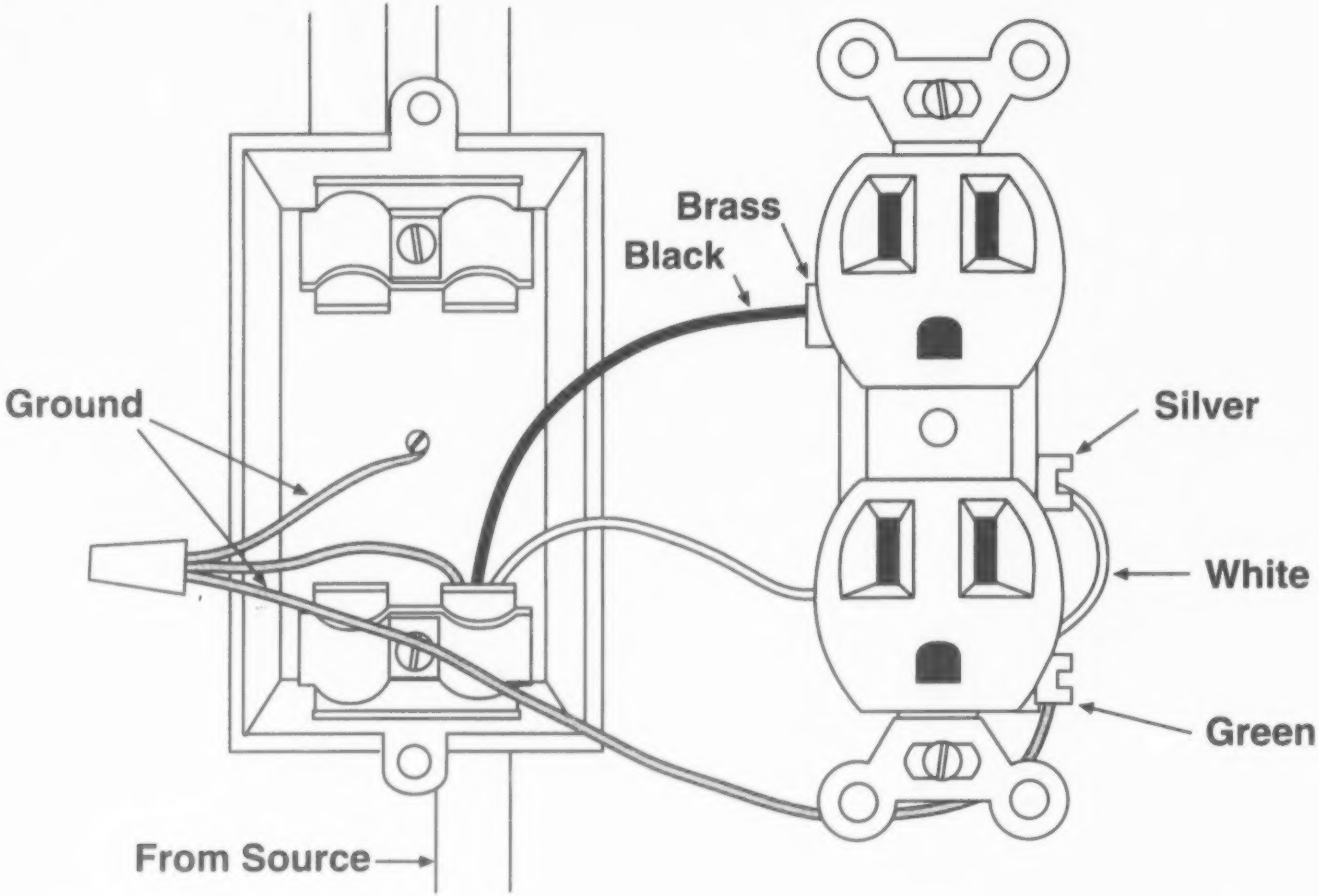
Series Electrical Connection


Return
Source

Parallel Electrical Connection


White
Black

Wiring a Convenience Outlet


Brass
Black
Ground
Silver
White
Green
From Source

Agricultural Structures, V-143

Lesson 9: Running Wire from the SEP

Name ____________________________

Wiring a Three-Way Switch

Objective: Wire a three-way switch to a light.

Materials and Equipment:

Mock wall with two switch boxes and one light fixture already attached
1 12-2 NMC cable, 16 inches long
2 12-3 NMC cables, 30 inches long
2 three-way switches
Light fixture
Solderless connectors
Three-prong plug
Screw driver set
Wire strippers
Cable rippers

Procedure:

1. Strip off six inches of the cable sheathing on one end of the 12-2 wire and both ends of the 12-3 wires.
2. Strip back 1 inch of insulation on all exposed wires. Bend hooks in the wires that will be connected to the switches or light fixture.
3. The 12-2 wire will be the power source. Attach the bared end of the 12-2 wire to one switch box with a box connector. Hot, neutral, and ground wires without sheathing should be in the box.
4. Using box connectors, attach one end of each of the 12-3 wires to a switch box and the other ends to the light fixture box.
5. At the first switch box
    a. Attach the black wire from the 12-2 cable to the common terminal of the switch.
    b. Attach the black wire from the 12-3 cable to the terminal opposite the black source wire.
    c. Connect a red wire to the third terminal.
    d. Connect the white source wire to another white wire with a connector.
    e. Connect the ground wires with a connector. With metal outlet boxes, run a 6-inch jumper wire from the ground wires to the box and attach it with a ground clip.
6. At the second switch box
    a. Connect the black wire from the 12-3 cable to the common terminal of the switch.
    b. Connect a red wire to the terminal opposite the black wire.
    c. Connect the white wire to the other terminal.
    d. Make the appropriate ground connections.

7. At the light fixture box
   a. Using a connector, connect the black wire from the first switch with the white wire from the second.
   b. Connect the red wires with a connector.
   c. Connect the black wire from the second switch to the brass screw on the light fixture.
   d. Connect the white wire from the first switch to the silver screw on the light fixture.
   e. Make the appropriate ground connections.
8. Remove 1 inch of the sheathing from the unconnected end of the 12-2 wire.
9. Open the three-prong plug casing and attach the 12-2 wire to the mounting screws, connecting the black wire to the brass terminal, the white wire to the silver terminal, and the green to the green.
10. Close the plug casing.
11. Have your instructor inspect all the connections.
12. Attach the switches and light fixtures to the boxes.
13. Place the cover plates on the switches.
14. Obtain a light bulb from your instructor and insert it into the light fixture.
15. Plug in the cord. Test the workings of the three-way switch.

UNIT V - ELECTRICITY

Lesson 10 : Cost and Electrical Power Use

Competency/Objective: Calculate cost and electrical power using Ohm's Law.

Study Questions

1. **What is the power equation, Ohm's Law, and their applications?**
2. **How is electricity measured?**
3. **How is the cost of electricity determined for each plan?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit V.
2. Transparency Masters
   - a) TM 10.1: Formulas
   - b) TM 10.2: Measuring Electricity
3. Activity Sheet
   - a) AS 10.1: Calculating Electrical Costs

UNIT V - ELECTRICITY

Lesson 10: Cost and Electrical Power Use

TEACHING PROCEDURES

A. ***Review***

Lesson 9 described how branch circuits are run to the individual outlets and light fixtures within agricultural structures. After the circuits are in place and electricity is available, calculating the power used in those systems becomes important. This lesson introduces the mathematical formulas needed to determine the amount of power used and explains how to calculate the cost of electricity.

B. ***Motivation***

Ask students if they know how to read an electric meter. If possible, show them a meter, and have them try to read it.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. When calculating power usage, four factors are important: wattage, voltage, amperage, and resistance. They are needed to find values for both the power equation and Ohm's Law, which is the basic mathematical formula for electrical power. Discuss the formulas and their use. Show students TM 10.1 to demonstrate how to multiply and divide to calculate the different values.

   What is the power equation, Ohm's Law, and their applications?

   a) Power equation
      1) Mathematical formula that expresses the amount of power used in an electrical circuit or system
      2) Indicates the relationship between wattage (P), amperage (I), and voltage (E)

$$P = I \times E$$

      3) Primarily used to calculate power usage in watts but can also be used to determine the amperage or voltage of a system
      4) Important when testing an electrical system for efficient operation and for calculating the power use of individual branch circuits or the total system

   b) Ohm's Law
      1) Mathematical formula that expresses the relationship between electromotive force (E), electric current (I), and resistance (R).
         (a) Electromotive force, measured in volts, is the pressure created by the movement of electrons.
         (b) Electric current is measured in amps.
         (c) Resistance is measured in ohms.

$$E = I \times R$$

      2) AC circuits - impedance (Z) rather than resistance
         (a) Impedance describes the counter electromotive force created by the directional change in the AC circuit.
         (b) The strength of the resistance depends on the rapidity of the directional change.

3) Determines the energy efficiency of an electrical circuit, looking at factors such as voltage drop.
   (a) It helps electricians determine if changes need to be made in a system.
   (b) The equation can also help in determining if it would be feasible to expand an existing system.

2. Obtaining accurate measurements of electrical consumption is necessary to calculate the cost of the electricity used. Explain how meters are used to monitor usage. TM 10.2 provides examples showing how to read one type of meter.

   How is electricity measured?

   a) Measured by power companies using a watt-hour meter, which measures and instantly records electrical consumption in watts or kilowatts
      1) Attached to the electrical system at the meter base
      2) Located at or near the service entrance panel in homes and on individual structures or at the power pole when a number of structures will be operating on the electrical service
   b) Commonly use two types of meters
      1) Newer type - uses a rotating meter similar to the mileage indicator on a car
      2) Older type - has several rotating pointers that turn as electricity is used
         (a) The first dial is read counterclockwise.
         (b) The second dial is read clockwise.
         (c) The third dial is read counterclockwise.
         (d) The fourth dial is read clockwise.
         (e) The numbers are written down from left to right.
         (f) If the pointer is between numbers, the smaller number is read.

3. Discuss how the cost of electricity is calculated. Bring in information on local rates and have students practice calculating the cost of electrical power. Hand out AS 10.1.

   How is the cost of electricity determined?

   a) Calculating the cost of electricity requires the rate scale from the electric company and the total kilowatt-hours consumed.
   b) To calculate the total use over a period of time, the previous meter reading is subtracted from the current one.
   c) The basic calculation involves multiplying the rates charged by the amount of electricity used.

F. ***Other Activities***

As students complete AS 10.1, ask them to track the daily usage of electrical power. Have them describe any fluctuations in daily usage and explain the cause of those fluctuations.

G. ***Conclusion***

The power equation and Ohm's Law measure the flow of electricity through the electrical system of agricultural structures. These formulas make it possible to calculate loads for each structure, check electrical costs, and plan for future expansion to meet electrical needs.

H. ***Answers to Activity Sheet***

I. ***Answers to Evaluation***

1. .91 amps, .73 amps

2. 83.33 volts, 1.33 volts
3. 720 watts, 4,800 watts
4. E = I × R, where E = electromotive force, I = electric current, and R = resistance
5. To describe the counter electromotive force created by the directional change in the AC circuit
6. Watt-hour meter
7. 1,111 watts used
   100 × $ .055 = $5.50
   200 × $ .045 = $9.00
   500 × $ .035 = $17.50
   311 × $ .025 = $7.78
   TOTAL = $39.78

UNIT V - ELECTRICITY Name ______________________________

Lesson 10: Cost and Electrical Power Use Date ______________________________

EVALUATION

Using the power equation, determine the missing values.

1. Find the amperes:
   a. Volts - 11 Watts - 100 ______________
   b. Volts - 240 Watts - 175 ______________
2. Find the volts:
   a. Watts - 500 Amps - 6 ______________
   b. Watts - 12 Amps - 9 ______________
3. Find the watts:
   a. Volts - 120 Amps - 6 ______________
   b. Volts - 240 Amps - 20 ______________

Complete the following short answer questions.

4. What is the formula for Ohm's Law for DC circuits? What does each of the variables represent?

5. Why is impedance (Z) used in the formula for Ohm's Law for AC circuits?

6. What device is used by power companies to measure the amount of electricity used?

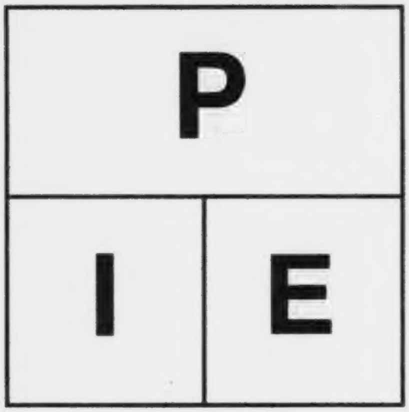
Calculate the cost of electricity for the problem below. Show your work.

7. Meter readings: Previous - 1,222 kWh Current - 2,333 kWh

Sliding rate scale:

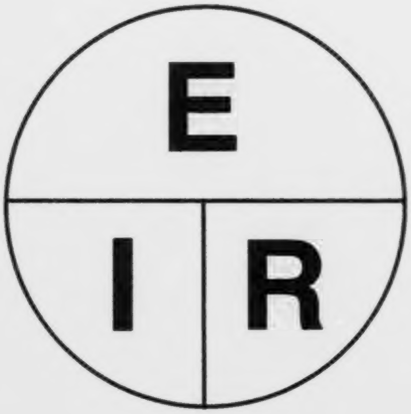
$ .055 for the first 100 kWh
$ .045 for the next 200 kWh
$ .035 for the next 500 kWh
$ .025 for the next 700 kWh
$ .01 for over 1500 kWh

Formulas



P = Wattage
I = Amperage
E = Voltage

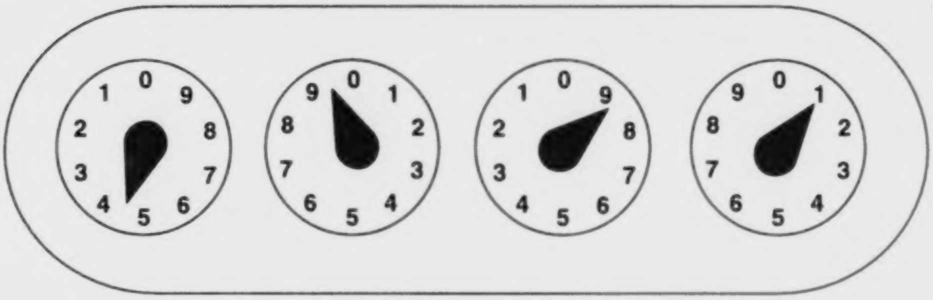
Note: Cover the letter of the value you wish to find to discover the method.



E = Voltage
I = Amperage
R = Resistance

Note: Cover the letter of the value you wish to find to discover the method.

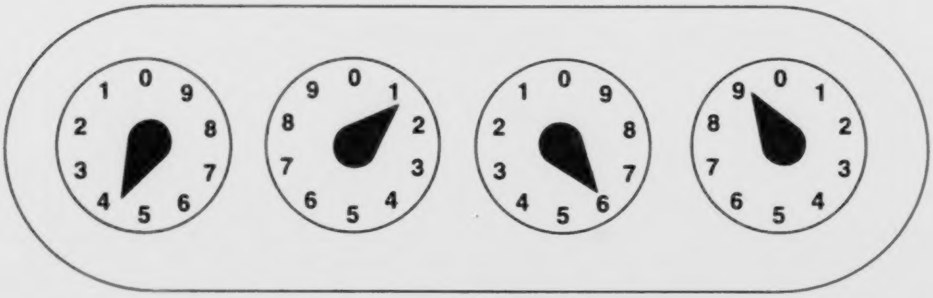
Measuring Electricity



July 15

First dial - number passed 4---
Next dial - number passed -9--
Next dial - number passed --8-
Right dial closest number ---1

Reading = 4981 kwh



June 16

First dial - number passed 4---
Next dial - number passed -1--
Next dial - number passed --6-
Right dial closest number ---9

Reading = 4169 kwh

4981- 4169 = 812 kwh used

Lesson 10: Cost and Electrical Power Use Name ____________________________

Calculating Electrical Costs

Objective: Calculate the cost of the electricity used in the home based on current local utility rates.

Keep a record of the power used at your home over a five-day period. Find out the local utility rates for your area from your parents or the utility company. At the end of the week, calculate the cost of electricity used. Show your work.

Meter reading:

Start - ____________________ kWh End - ____________________ kWh

Utility rate:

Weekly usage:

Cost:

UNIT V - ELECTRICITY

Lesson 11: Lightning Protection

Competency/Objective: Describe procedures for planning and installing lightning protection.

Study Questions

1. **What is lightning, and why does it strike structures?**
2. **What lightning protection is necessary for the operation?**
3. **What constitutes a good system of protection?**
4. **How is the lightning protection system installed?**
5. **How is equipment protected from lightning?**
6. **How is lightning grounded off a structure?**

References

1. *Agriculture Structures (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit V.
2. Transparency Masters
    a) TM 11.1: When Lightning Strikes
    b) TM 11.2: Components of a Lightning Protection System
    c) TM 11.3: Grounding Practices
3. Activity Sheet
    a) AS 11.1: Assessing Lightning Protection

Lesson 11: Lightning Protection

A. ***Review***

Lesson 10 described the formulas used to measure the consumption of electricity and the cost of electricity. Lesson 11 discusses efficient lightning protection systems. Lightning protection is important because lightning strikes can overload electrical systems, damage structures, and injure or kill people and animals.

B. ***Motivation***

Use a 6-volt battery to demonstrate how electricity jumps from a negative to a positive pole to demonstrate how electrons jump between the clouds and earth to create lightning. Attach a short wire to the positive electrode of the battery and another to the negative electrode. Move the wires together until a spark appears. Use a capacitor attached to the positive wire to increase the voltage for a longer arc.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Ask students to explain what lightning is and why it occurs. Discuss their answers, explaining why lightning strikes structures. TM 11.1 can be used to help illustrate the conditions that produce lightning. Emphasize that more than 125 people are killed by lightning each year.

   What is lightning, and why does it strike structures?

   a) Lightning
      1) It is the visible discharge of static electricity within a cloud, between clouds, or between the earth and a cloud.
      2) It is basically a large electric spark caused when current jumps a gap in the air.
   b) Strikes
      1) Strikes occur when hot and cold air masses meet, causing atoms to lose electrons.
      2) Negatively charged electrons gather at the cloud base.
      3) Positive ions converge at high locations on the earth's surface.
      4) The ions and electrons are attracted to each other, creating a stepped leader, an unseen conduit through which negative charges move from the cloud to the earth.
      5) From the earth, ion streamers called leaders travel upward.
      6) If the two puncture the air gap insulator and converge, a channel is created for electrical energy to move between the earth and the cloud as the charges rapidly equalize themselves.

2. Lightning protection is necessary not only to prevent injuries and fatalities but also to provide protection against fires and damage from electrical surges. Discuss the factors to consider when determining what lightning protection is needed by an agricultural operation.

   What lightning protection is necessary for the operation?

   a) Before installing lightning protection, the need for such protection should be assessed.
      1) Frequency of lightning
      2) Type of structure and its construction

        3) Location of the structure
        4) Topography of the surrounding area
        5) Contents of the structure
    b) Tall structures such as silos should be grounded not only to protect them but because they can provide a cone of protection with a diameter that is two times the height of the object.
    c) Electric fences should be grounded.

3. Ask students what components make up a lightning protection system. Show them TM 11.2 and describe the purpose of the different components pictured.

    What constitutes a good system of protection?

    a) Air terminals or lightning rods
        1) The points where lightning strikes
        2) Installed on high points on structures, such as roof ridges or ventilators
    b) Main conductors - cables that connect the air terminals to the grounding electrodes, or ground terminations
    c) Ground terminations - copper or copper-clad rods driven into the earth, preferably to a minimum of ten feet in depth
    d) Lightning arresters - protect wiring from lightning-induced damage
    e) Surge suppressors - used to further protect electrical equipment, such as computers

4. Proper installation of a lightning protection system is crucial to its efficiency. Describe the guidelines for installing lightning protection. Emphasize that having a professional install the system will provide the best protection by ensuring that it has been done properly.

    How is the lightning protection system installed?

    a) Number of grounding electrodes
        1) All buildings with a perimeter of 250 feet or less must have two grounding electrodes, preferably diagonally at opposite corners of the structure.
        2) If the perimeter is between 250 and 350 feet, three electrodes are required.
        3) At perimeters of 350 to 450 feet, four electrodes are necessary.
        4) Another grounding electrode is added for every 100 feet of perimeter.
    b) Grounding conductors
        1) They should follow a straight horizontal or vertical path to the grounding electrode.
        2) The cables need to be free of sharp turns and "U" or "V" pockets.
        3) Turns in conductors should not exceed 90 degrees.
        4) Bends should not have a radius of less than eight inches.
    c) Air terminals - should be properly sized, spaced, and installed
    d) Conductors
        1) The down conductors should carry the discharge directly to the ground.
        2) Entrance conduits, gutters, drain pipes, pipe vents, metal water pipes, radio and T.V. antennas, metal roofing, fences, and other metal objects should be bonded to the down conductors and ground rods.
        3) The main bonding conductors must be at least AWG 6 copper wire or its equivalent.
        4) Down conductors should be enclosed in a conduit or metal tubing extending from a point at least five feet above ground level to one foot below the ground's surface.
    e) Ground rods
        1) Ground rods of adequate size must be located properly throughout the system.
        2) Lightning system ground rods must be driven to a minimum depth of 10 feet where soil conditions permit.
        3) Other acceptable options are to dig a trench 3 to 4 feet deep by 10 feet long and bury a grounding rod or to bury a grounding plate at least 18 inches deep.
        4) Another method involves connecting down conductors to a metal water system, as long as the pipes are a minimum of three feet deep and ten feet long and are in direct contact with the earth.

        5) If ground rods used for the electrical or telephone system are within 6 feet of a grounding electrode, they must be bonded together to prevent side flashes.

5. Providing protection to equipment is another important function of lightning protection systems. Discuss the methods used to prevent damage to equipment.

How is equipment protected from lightning?

- a) Power supply system
    - 1) Stepping down
        - (a) Power from the source passed through several transformers and other devices
        - (b) Reduce and convert the electricity into forms the consumer can use
    - 2) Offers lightning protection at each level
- b) Surge suppressor
    - 1) Used to protect electronic equipment, particularly computers, from surges
    - 2) Provide a receptacle or a bank of receptacles with a breaker that automatically trips when the electricity spikes
    - 3) Prevent damage from lightning if computer equipment is plugged into telephone lines
        - (a) Telephone companies - lightning suppression devices in the lines
        - (b) Special surge suppressors - connections for telephone lines
- c) Lightning or surge arrester
    - 1) Used to remove high voltage charges from the system by breaking the circuit and then diverting the electricity to the ground
    - 2) Installed where service wires enter the building at the service entrance panel or prior to the connection of specialized electrical loads or other equipment away from protected buildings
- d) Controller
    - 1) Normally used for starting and stopping motors
        - (a) For small motors of ⅛ hp or less - overcurrent device at the service entrance panel
        - (b) For larger motors - separate switch with a current capacity at least twice the full load rating of the motor
    - 2) Should have overload devices installed that stop the current to the motor during electrical surges and power overloads
    - 3) Should also have a manual reset so the motor does not restart automatically when normal power is restored

6. The grounding of the lightning protection system will determine the extent of protection available. Discuss how lightning is grounded off a structure. TM 11.3 shows grounding practices for a building. Have students complete AS 11.1.

How is lightning grounded off a structure?

- a) Electrical grounding - connecting one end of a properly sized copper conductor to the air terminals and the other end to a metal conductor that is in direct and permanent contact with the earth
- b) Grounding
    - 1) ½-inch copper rod
    - 2) ⅝-inch copper-clad rod
    - 3) ¾-inch galvanized iron pipe
    - 4) Metallic water system
    - 5) Metal plate if a ground rod cannot be used due to rock beneath the soil
- c) Size of the grounding wire determined by the size of the wire supplying power to the service entrance panel
- d) Wire clamped to the grounding electrode using lugs or clamps

F. *Other Activities*

Invite a certified electrician or a professional who installs lightning protection systems to give a presentation to the class about his or her work.

G. *Conclusion*

Lightning can be dangerous to humans and animals and destructive to structures and equipment. An efficient lightning protection system is necessary to help prevent damage and loss of life. For the best possible protection, a qualified and certified professional should install systems for the home and farm.

H. *Answers to Activity Sheet*

I. *Answers to Evaluation*

1. d
2. d
3. c

4. Answers may include any two of the following: frequency of lightning, type of structure and its construction, location of the structure, topography of the surrounding area, and contents of the structure.

5. They are the points where the lightning strikes.

6. A channel is created for electrical energy to move between the earth and the cloud.

7. To dig a trench 3 to 4 feet deep by 10 feet long and bury a grounding rod or to bury a grounding plate
8. The size of the wire supplying power to the service entrance panel
9. Used to protect electronic equipment, particularly computers

UNIT V - ELECTRICITY Name ____________________________

Lesson 11: Lightning Protection Date ____________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. How many ground rods are required for a structure with a perimeter of 410 feet?

   a. 1
   b. 2
   c. 3
   d. 4

2. Before lighting strikes, ______________________ travel(s) upward from the earth.

   a. Electrons
   b. Ions and electrons
   c. A stepped leader
   d. An ion streamer

3. What size copper wire should be used for the main bonding conductors?

   a. AWG 2
   b. AWG 4
   c. AWG 6
   d. AWG 8

Complete the following short answer questions.

4. What are two factors to consider when assessing the need for lighting protection?

   a.

   b.

5. What is the function of air terminals?

6. What happens when the air gap insulator is punctured?

7. What are two alternative methods of establishing a grounding electrode if one cannot be driven to the proper depth?

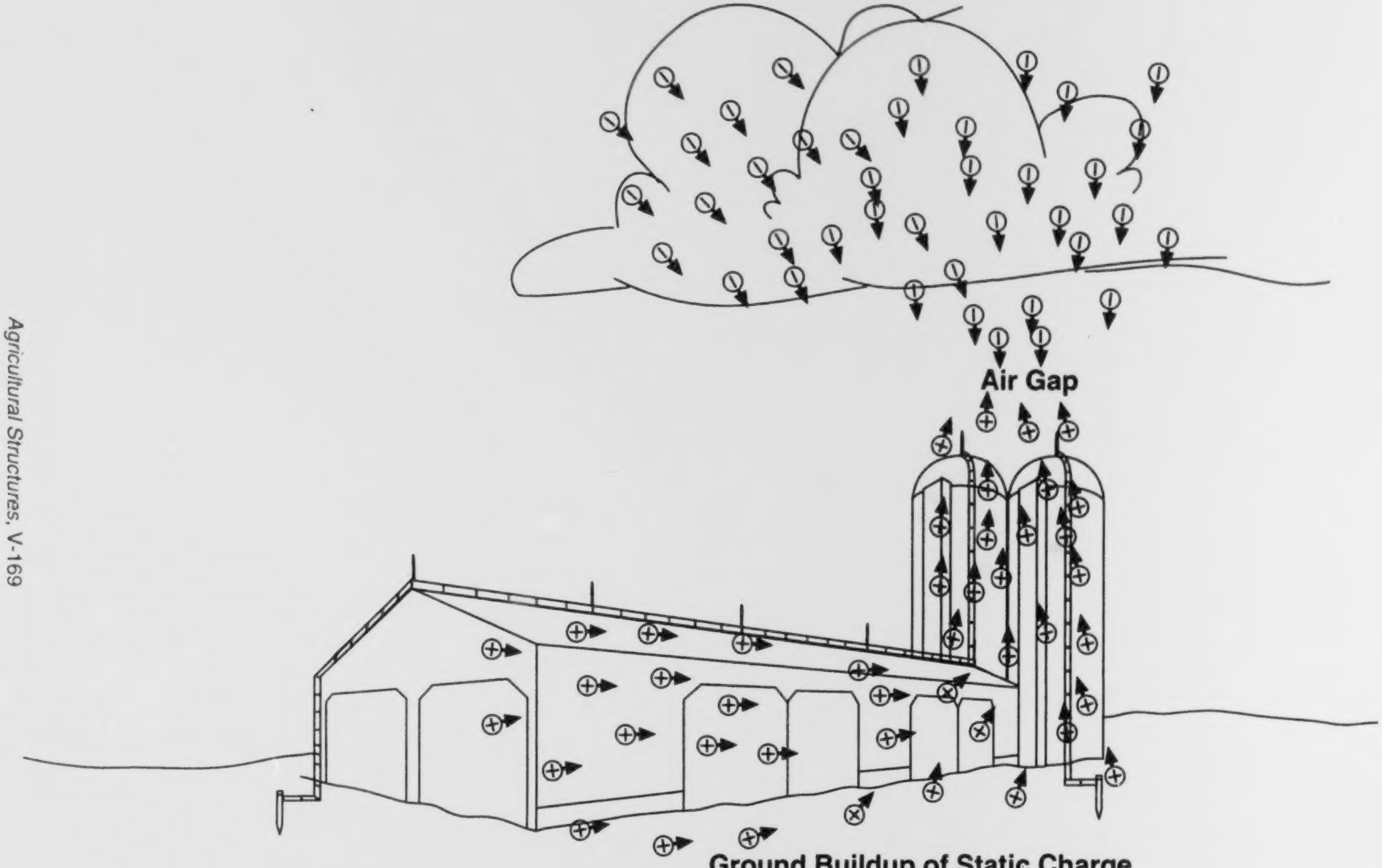
   a.

   b.

8. What determines the size of the grounding wire?

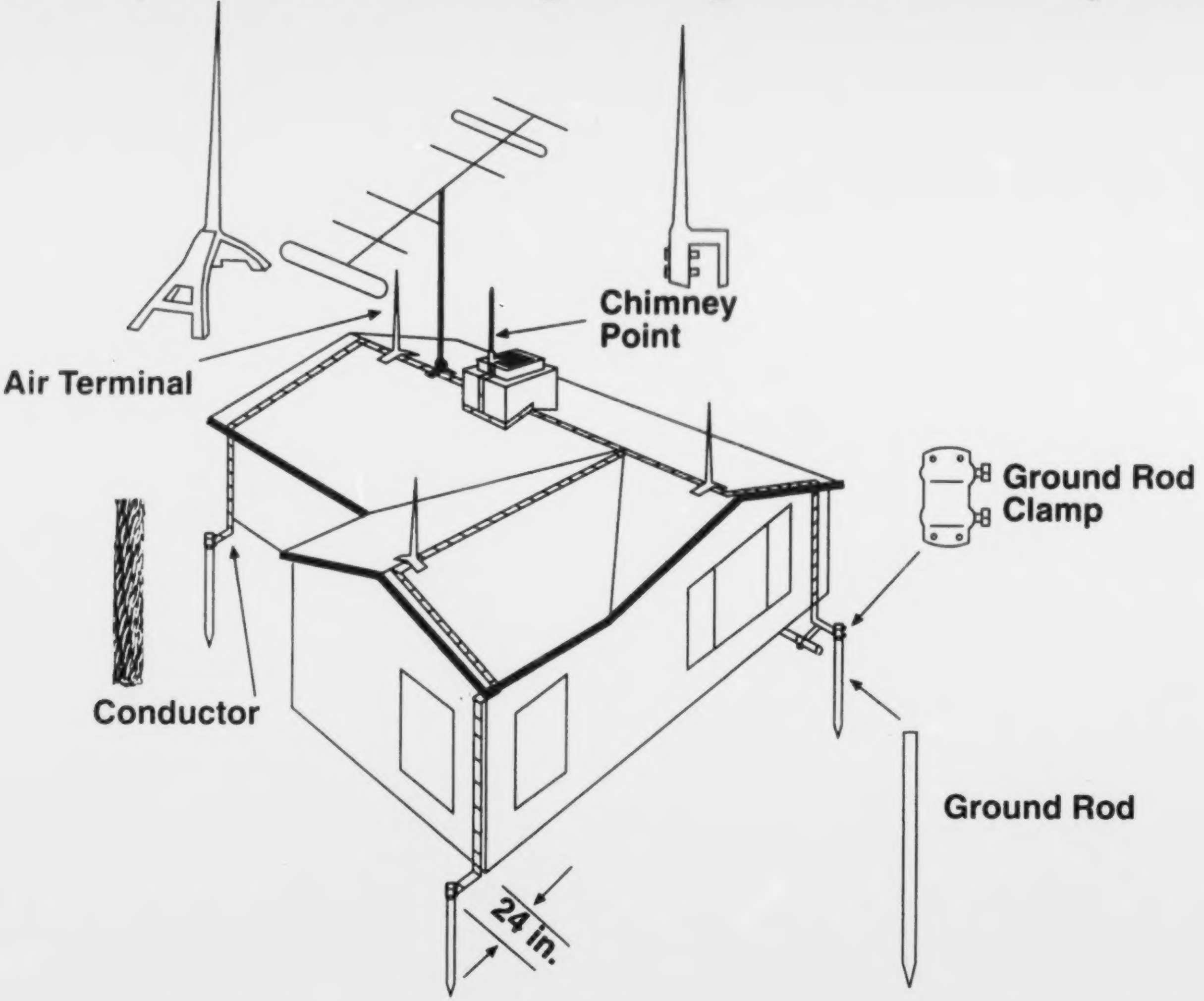
9. What is the function of surge suppressors?

When Lightning Strikes


Air Gap
Ground Buildup of Static Charge

When the force is great enough to puncture the air gap, the charge follows the path of least resistance to the ground.

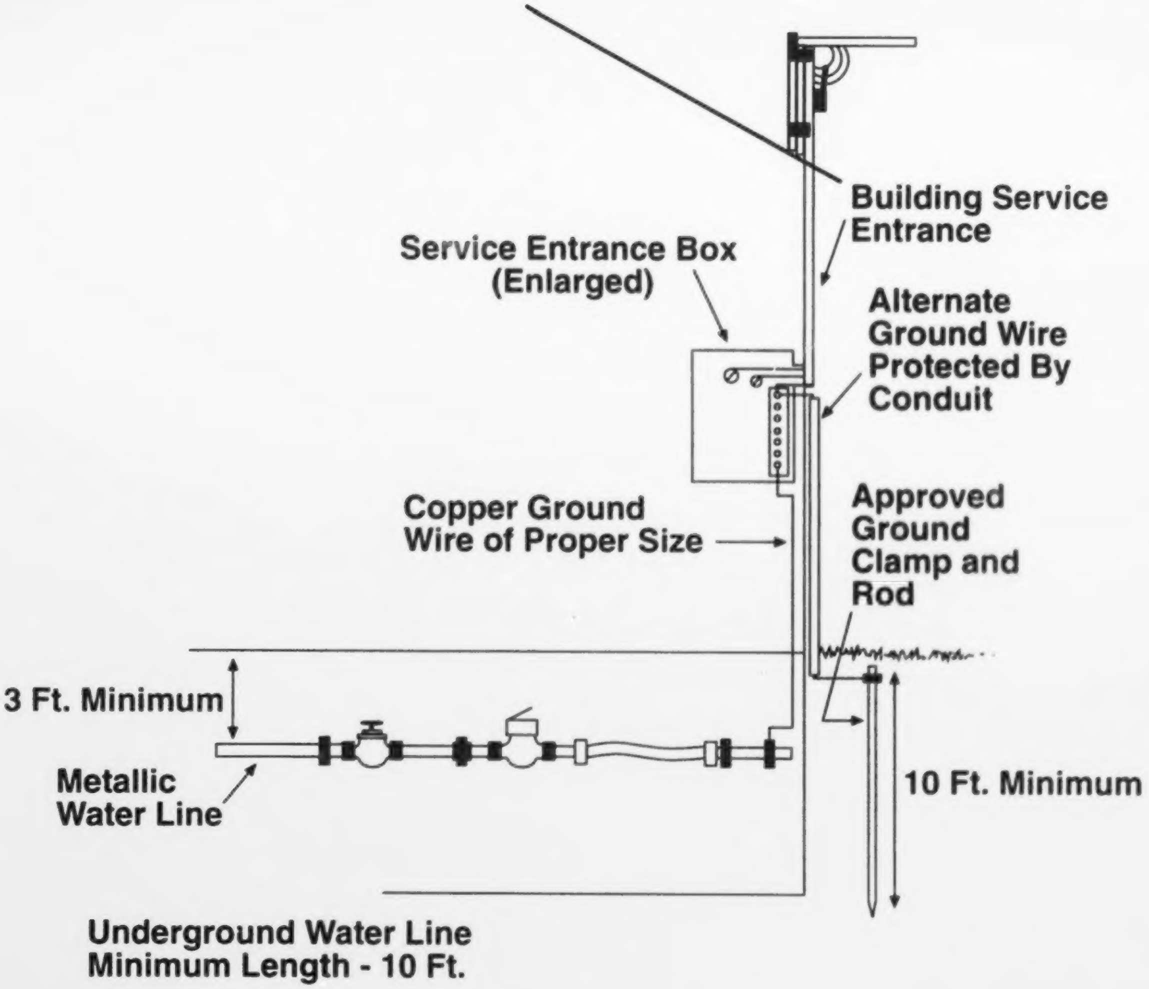
Components of a Lightning Protection System


Air Terminal
Chimney Point
Ground Rod Clamp
Conductor
Ground Rod
24 in.

Agricultural Structures, V-171

TM 11.2

Grounding Practices


Building Service Entrance
Service Entrance Box (Enlarged)
Alternate Ground Wire Protected By Conduit
Copper Ground Wire of Proper Size
Approved Ground Clamp and Rod
3 Ft. Minimum
Metallic Water Line
10 Ft. Minimum
Underground Water Line Minimum Length - 10 Ft.

Lesson 11: Lightning Protection

Name ______________________________

Assessing Lightning Protection

Objective: Identify the components of the lightning protection system in a structure.

Investigate the lightning protection system installed in your home or an agricultural structure. Identify the components of the system and fill out the chart. If no lightning protection is present, indicate what components would be needed and where they would be installed.

Components	Number	Location
Air terminals		
Down conductors		
Ground terminations		
Lightning arresters		
Surge suppressors (telephone/electrical)		

406

Lesson 12: Detecting Problems

Competency/Objective: Identify problems in electrical systems.

Study Questions

1. **What types of testers are used in troubleshooting?**
2. **How are the testing devices used?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit V.
2. Transparency Master
    - a) TM 12.1: Types of Electrical Testers
3. Activity Sheet
    - a) AS 12.1: Using Testing Devices

TEACHING PROCEDURES

A. ***Review***

Lesson 11 described how to protect electrical systems from lightning. Lightning is not the only potential cause of problems, however. After an electrical system is installed, problems caused by poor wiring practices, misuse, or wear can occur. This lesson will focus on troubleshooting electrical problems, particularly the use of electrical testers.

B. ***Motivation***

Ask students the following questions. Discuss their answers, pointing out that the problems described are all common and must be addressed to safely and efficiently provide electrical power.

- Have any of you experienced breakers tripping on a repeated basis?
- Are there any electrical outlets in your home that do not function properly?
- Have you ever felt a tingle when plugging or unplugging a cord in an outlet?

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Identifying and correcting electrical problems involves the use of different testing devices that make it possible to safely and easily detect problems. Discuss these devices, using TM 12.1 to illustrate them.

What types of testers are used in troubleshooting?

a) Neon tester
    1) Simplest device used by electricians
    2) Used on either a 120-volt or 240-volt system
    3) Glowing light - indicates that voltage is present; the greater the voltage, the brighter the light
b) Voltage tester
    1) Used to indicate the voltage and polarity, or direction of electrical flow, in a circuit
    2) Uses a series of neon lights to indicate the approximate voltage moving through the circuit
c) VOM (volt-ohm-milliammeter) meter
    1) Displays the voltage and polarity of the circuit; also provides accurate measurements of circuit resistance and amperage
    2) Combines a voltmeter, ohmmeter, and ammeter in one casing
        (a) Voltmeter - measures voltage across two points in an electrical circuit
        (b) Ohmmeter - measures resistance
        (c) Ammeter - measures the electrical flow or amperage
    3) Provides information on a calibrated numerical scale

2. Explain how to use the testing devices listed. Emphasize that the manufacturer's directions for the proper use of these testing devices should be understood prior to their use. Have students complete AS 12.1. It may be appropriate to create a malfunction in the receptacle tested.

Students could also add an outlet receptacle to the electrical board described in AS 9.1 that could be made to malfunction for testing.

How are the testing devices used?

a) Neon tester for testing outlet receptacles
   1) Place the ends of the leads into the parallel slot openings; if the tester lights up, no problem exists.
   2) If the tester does not light up, insert the end of one of the leads into the ground opening, with the other lead in one of the other slots.
   3) If the tester lights up, the problem is with the neutral connection or the neutral wire.
   4) If the tester still does not glow, remove the outlet cover plate and receptacle.
   5) Touch the leads to the opposite terminal screws.
   6) If the tester lights up, the receptacle does not function and should be replaced.

b) Voltage tester for outlets, switches, fixtures, and other electrical devices
   1) It works in a similar way as the neon tester.
   2) The tester also indicates whether an electrical system carries 120 volts or 240 volts as well as its polarity.

c) VOM meter
   1) The leads are color coded, with red used for the power side and black for return or neutral side of the circuit during testing.
   2) The leads are used as they are with the other testers.
   3) The ohmmeter contains its own power source, so all power to the electrical system should be disconnected before testing for circuit resistance.

F. *Other Activities*

Using a VOM meter, test a switch.

G. *Conclusion*

To troubleshoot electrical systems, it is important to be competent in the use of various testing devices. A problem can only be fixed if it can be identified.

H. *Answers to Activity Sheet*

I. *Answers to Evaluation*

1. d
2. b
3. c
4. Volt-ohm-milliammeter
5. Faulty receptacle
6. Using a series of neon lights

UNIT V - ELECTRICITY

Name ______________________________

Lesson 12: Detecting Problems

Date ______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. The power should be disconnected when using the ___________________.

    a. Neon tester
    b. Voltage tester
    c. Voltmeter
    d. Ohmmeter

2. On a voltmeter, what is the color of the lead that is used for the power side of the circuit?

    a. White
    b. Red
    c. Black
    d. Green

3. What does the glowing light on a neon tester indicate?

    a. Resistance
    b. Amperage
    c. Voltage
    d. Polarity

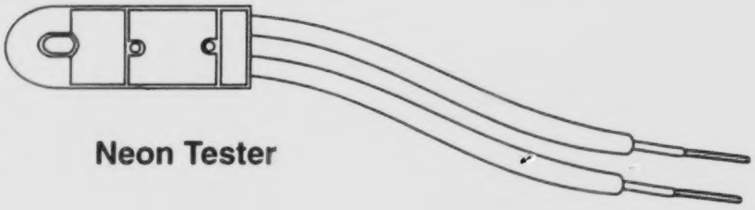
Complete the following short answer questions.

4. What does VOM mean?

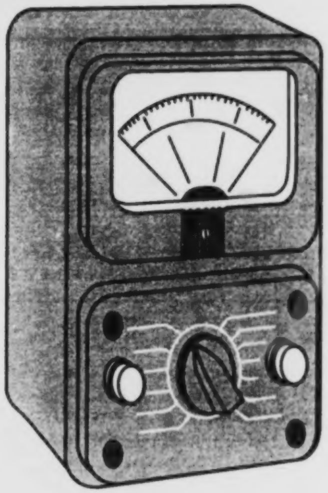
5. When testing an outlet receptacle with the neon tester, you find that the tester lights up only when you touch the leads directly to the terminal screws of the outlet. What is the problem?

6. How does the voltage tester indicate the approximate voltage moving through the circuit?

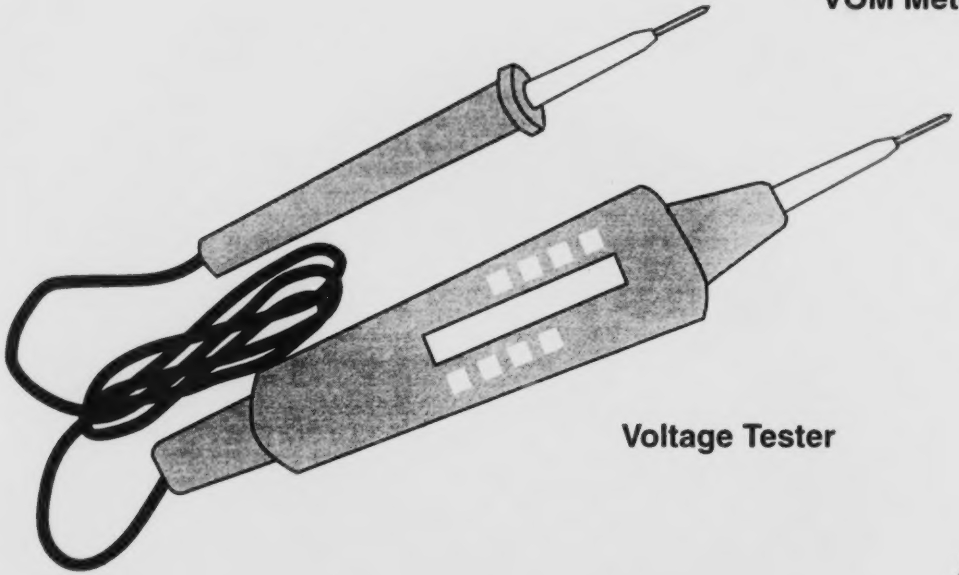
Types of Electrical Testers



Neon Tester



VOM Meter



Voltage Tester

Agricultural Structures, V-183

TM 12.1

Lesson 12: Detecting Problems

Name ______________________________

Using Testing Devices

Objective: Use an electrical testing device to test an outlet receptacle for power.

Use the different testing instruments described in this lesson to test an electrical outlet chosen by your instructor. Fill in the table, describing the types of information provided by the different testers, the procedures followed to conduct the test, and the results of the test.

Type of Tester	Information Provided	Test Procedure and Results
Neon tester		
Voltage tester		
VOM meter		

UNIT VI - PLUMBING

Lesson 1: Water Needs

Competency/Objective: Calculate how much water is needed for a farmstead.

Study Questions

1. **What are the sources of water on a farmstead?**
2. **What are the uses of water on a farmstead?**
3. **How is the total daily water need determined?**
4. **How is peak water need determined?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit VI.
2. Transparency Master
    a) TM 1.1: Water Needs Table
3. Activity Sheet
    a) AS 1.1: Determining Water Needs

UNIT VI - PLUMBING

Lesson 1: Water Needs

TEACHING PROCEDURE

A. ***Introduction***

Agricultural operations depend on their water supply for production. Determining which water sources are suitable for an operation and the volume of water required are essential to the success of the producer.

B. ***Motivation***

Ask students if they know how much water each of them consumes (total water use) on a daily basis (approximately 50 to 100 gallons per day). Then ask them to list as many different uses of water in agricultural operations as they can. Can any operations exist without water?

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Ask students to list different sources of water with which they are familiar. Discuss the sources of water for agricultural operations.

   What are the sources of water on a farmstead?

   a) Public water supply
      1) Provides a safe, dependable water supply
      2) Not available in all areas, making private water sources necessary
   b) Well
      1) Provides a large quantity of safe water with relatively little maintenance
      2) Either shallow or deep
         (a) Shallow wells - sufficient water but poorer in quality
         (b) Deep wells - cleaner water and usually a larger volume of water; more expensive to drill
   c) Cistern - stores rainwater for domestic use but may not supply enough for livestock
   d) Pond
      1) Natural or man made
      2) Supplies livestock with water
      3) Can be used for humans with the proper construction and purification
      4) Problem - protection from pollution
   e) Natural sources of water, such as creeks, streams, and springs
      1) May not be able to provide enough water to meet the needs of the operation
      2) Can be unreliable for most irrigation and animal needs because of flooding, droughts, and changing topography of water courses

2. Refer back to the motivation and discuss the uses of water that predominate at their homes or operations. Discuss the different uses.

   What are the uses of water on a farmstead?

   a) Drinking water for livestock
   b) Irrigating crops

    c) Sanitation
    d) Cooling systems in some types of facilities, such as greenhouses or hog facilities
    e) As a delivery system, by adding fertilizer to water while irrigating or medication to animals' drinking water
    f) Human use for various domestic purposes, if a home is located on the farmstead

3. Ask students how they would go about determining how much water an agricultural operation needs on a daily basis. Using TM 1.1, discuss the use of tables showing water needs for different applications. Point out that overestimating daily water needs is usually better than underestimating the amount.

   How is the total daily water need determined?

   a) Find information on water needs.
      1) Charts that show the water needs for different types of animals and crops or special circumstances
      2) Local University Extension offices
      3) Trade associations
   b) Multiply the recommended amount of water for a particular use by the amount of usage.
   c) Add the different water uses together to find the total daily need of the operation.

4. Ask students how peak water need is determined. Have students complete AS 1.1.

   How is peak water need determined?

   a) The volume of water a water source can deliver is usually measured in gallons per hour.
   b) Compare the total daily needs with the hourly output, which should be greater than the daily needs of the operation in order to meet peak water needs.

F. *Other Activities*

Have students determine their water needs at home. Have them find out whether their water source is sufficient.

G. *Conclusion*

Water, which may come from a variety of different sources, is a necessity for agricultural production. With a bit of calculating, a producer can estimates the amount that will be needed for his or her operation. This information can be useful when planning water systems.

H. *Answers to Activity Sheet*

Category	Water Needs
Humans - 4 adults	400
25 beef cows	300
15 calves	150
4 horses	48
Lawn watered weekly - 1 inch (2,000 square feet)	1200
100 sows	800
Flushing the floor of the barn (400 square feet)	40
Total water needs	2938

1. No

2. 402 gallons

3. Drill another well, or reduce the number of hogs raised.

I. ***Answers to Evaluation***

1. c
2. a
3. Local University Extension offices and trade associations

4. Answers may include any three of the following: drinking water for livestock; irrigating crops; sanitation; cooling systems in some types of facilities; as a delivery system, by adding fertilizer to water while irrigating or medication to animals' drinking water; and use by humans for various domestic purposes, if a home is located on the farmstead.

5. By multiplying the recommended amount of water for a particular use by the amount of usage and adding the different water uses together to find the total daily need of the operation

6. By comparing the total daily needs with the hourly output

UNIT VI - PLUMBING

Lesson 1: Water Needs

Name ______________________________

Date ______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following sources of water holds rainwater for domestic use?

   a. Public water supplies
   b. Wells
   c. Cisterns
   d. Springs

2. What is a potential problem in using a pond as a water source?

   a. Pollution
   b. Flooding
   c. Maintenance
   d. Water storage

Complete the following short answer questions.

3. What are two potential sources of information about water needs?

   a.

   b.

4. What are three uses of water by agricultural operations?

   a.

   b.

   c.

5. How is the total daily water need calculated for an agricultural operation?

6. How is peak water need determined?

Water Needs Table

Use	Water Needs
Adult human	50 to 100 gallons per day
Beef animal	8 to 12 gallons per day
Milk cow	35 to 45 gallons per day
Dry cow	20 to 30 gallons per day
Calf	6 to 10 gallons per day
Swine (finishing)	3 to 5 gallons per day
Sow and litter	8 gallons per day
Horse	12 gallons per day
100 chickens (laying)	9 gallons per day
Lawn and garden	600 gallons to apply 1 inch of water on 1,000 square feet of area
Flushing floors	Minimum of 10 gallons per 100 square feet of floor

*Adapted from *How to Size a Farm and Home Water System (G1801)*, a University of Missouri Extension agricultural publication.

UNIT VI - PLUMBING AS 1.1

Lesson 1: Water Needs Name ______________________

Determining Water Needs

Objective: Determine if the water supply is sufficient to supply this farm's water needs.

You are considering adding a 100-sow hog enterprise to your farm. One of your main concerns is whether the single well on the farm will be enough to supply the entire farm's needs, including the new hog operation. You will use water for the hogs and for flushing the floor of the barn. Your well provides 2,500 gallons. Using the information from the chart in the student reference, determine the total daily water needs for the farm. Use the maximum numbers for each category when determining your water needs. Then answer the questions below.

Category	Water Needs
Humans - 4 adults	__________
25 beef cows	__________
15 calves	__________
4 horses	__________
Lawn watered weekly - 1 inch (2,000 square feet)	__________
100 sows	__________
Flushing the floor of the barn (400 square feet)	__________
Total water needs	__________

1. Will your well supply enough water to add 100 sows?

2. How much extra water do you have without the hogs?

3. What are your alternatives for dealing with this water shortage?

UNIT VI - PLUMBING

Lesson 2: Plumbing Safety

***Competency/Objective*:** Discuss safety practices for plumbing.

Study Questions

1. **What are the different hazards associated with plumbing?**
2. **What are the tools needed for safe plumbing practices?**
3. **What are the proper methods for using tools and supplies associated with plumbing?**

References

1. *Agricultural Structures (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit VI.
2. Transparency Masters
   a) TM 2.1: Cutting Tools for Copper Pipe
   b) TM 2.2: Flaring and Bending Tools
3. Activity Sheet
   a) AS 2.1: Working with Plumbing Safely

UNIT VI - PLUMBING

Lesson 2: Plumbing Safety

TEACHING PROCEDURES

A. ***Review***

Many agricultural structures require some plumbing construction or repairs. Much of this work may be performed without outside help. A basic understanding of possible hazards and basic plumbing tools and their use is therefore desirable to perform these activities safely.

B. ***Motivation***

Ask students if they have heard of or seen any accidents associated with working with plumbing. If possible, bring in newspaper clippings about serious accidents, such as trench cave-ins. Discuss the importance of safety.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Referring back to the motivation, ask students to list some of the hazards associated with plumbing activities.

   What are the different hazards associated with plumbing?

   a) Open trenches
      1) People can suffocate if the sides cave in and bury them.
      2) The sides should be carefully observed for signs of instability, such as loose and collapsing areas.
      3) These areas should be avoided until they have been excavated to a safe point.
      4) Heavy excavating equipment close to the sides of a trench can cause the earth to cave in.
      5) The equipment should be removed before anyone enters the area.
   b) Plastic pipes cleaners and glues containing strong chemicals
      1) They may produce very strong, sometimes toxic, fumes.
      2) They may also irritate the skin.
      3) They can be flammable.
   c) Fire
      1) In areas where septic or waste lines are present, methane gas may accumulate; it is flammable and can explode.
      2) A potential fire hazard occurs when using a propane torch, because the flame can cause a fire if it comes into contact with combustible materials.
   d) Disorganized, untidy work sites
      1) Tripping and falling are common causes of injuries.
      2) Small sections of pipe left lying around can be particularly hazardous, since they tend to roll when stepped on.
      3) Ladders can tip over if they are not set on a level, solid surface.

2. Display examples or pictures of the tools with which students may not be familiar. Discuss other tools that are needed when working with plumbing. TMs 2.1 and 2.2 show different tools for working with copper pipe.

What are the tools needed for safe plumbing practices?

a) General tools for plumbing practices
  1) Shovel for digging shallow trenches for pipe
  2) Heavy earth-moving equipment for deeper trenches
  3) Level
  4) Claw hammer
  5) Ladder
  6) Tape measure
  7) Drill

b) Plastic pipe
  1) Adjustable wrench
  2) Hacksaw to cut pipes
  3) Sandpaper, a knife, or a scraping tool for smoothing the rough edges of pipe that has been cut
  4) Pipe cleaner to remove residue from cutting
  5) Pipe glue to join pipes

c) Copper pipes
  1) Propane torch and soldering material to join pipes together
  2) Pipe cutter
  3) Pipe bender
  4) Reamer to remove sharp edges after cutting the pipe
  5) Flaring tool to widen the end of the pipe

3. Describe the practices that should be followed to use plumbing tools safely. If possible, demonstrate the safe use of some of the tools brought in as examples for the previous question.

What are the proper methods for using tools and supplies associated with plumbing?

a) Use protective clothing and gear.
  1) Heavy work pants
  2) Boots
  3) Gloves
  4) Eye protection
  5) Safety helmet, if injury from above is possible

b) All tools should only be used according to the manufacturer's recommendations.

c) When utilizing plastic pipe cleaners and cements, special attention should be given to any safety recommendations concerning ventilation, skin contact, or fire hazards.

d) Extreme caution should be used when working with a propane torch; proper ventilation and the use of the protective clothing and gear listed above are a must.

F. *Other Activities*

Ask a local plumber or a representative from a plumbers' union to come and speak to the class about plumbing safety.

G. *Conclusion*

Being aware of the potential hazards and safety practices outlined above can reduce the chance of accidents while performing plumbing work. Safety should always be considered first to avoid accidents whenever possible.

H. *Answers to Activity Sheet*

For each of the questions, examples given as answers may vary.

1. Fire

2. Ventilation
3. Cave-in
4. To avoid tripping

I. *Answers to Evaluation*

1. d
2. e
3. a
4. b
5. c
6. g
7. f

8. Answers may include any two of the following: heavy work pants, boots, gloves, eye protection, and safety helmet.

9. People can suffocate if the sides cave in and bury them.

10. Methane gas
11. Safety recommendations concerning ventilation, skin contact, or fire hazards
12. Because they can be particularly hazardous in terms of causing falls, as they tend to roll when stepped on

UNIT VI - PLUMBING
Name ____________________

Lesson 2: Plumbing Safety
Date ____________________

EVALUATION

Match the description in the column on the left with the tool in the column on the right.

1. _____ Used for digging shallow trenches
2. _____ Tool for cutting pipes
3. _____ Tool used to smooth rough edges on cut pipe
4. _____ Used to join copper pipes together
5. _____ Removes residue from cutting
6. _____ Used to widen the end of copper pipe
7. _____ Joins plastic pipe together

a. Knife
b. Propane torch
c. Pipe cleaner
d. Shovel
e. Hacksaw
f. Pipe glue
g. Flaring tool

Complete the following short answer questions.

8. What are two items of protective clothing that can be worn to prevent injury?

   a.

   b.

9. Why can open trenches be dangerous?

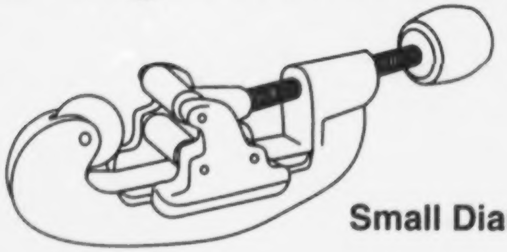
10. What is the name of the flammable gas that can accumulate around septic lines?

11. When utilizing pipe cleaners and cements, what types of safety recommendations are important?

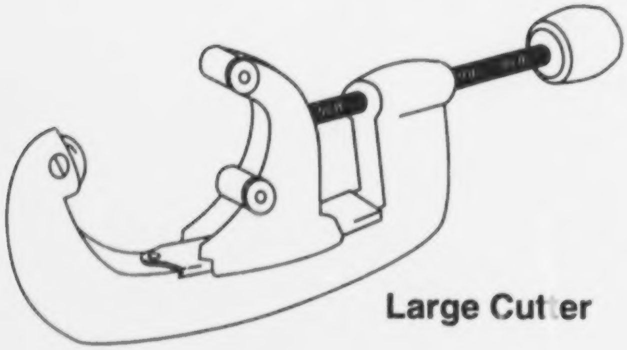
12. Why should small sections of pipe always be picked up immediately?

TM 2.1

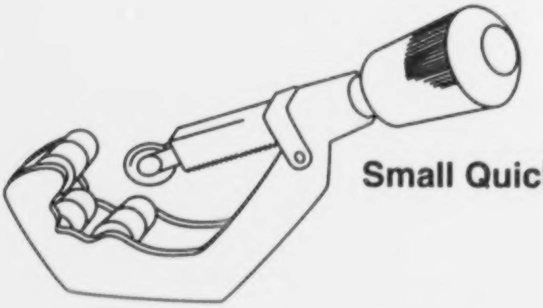
Cutting Tools for Copper Pipe



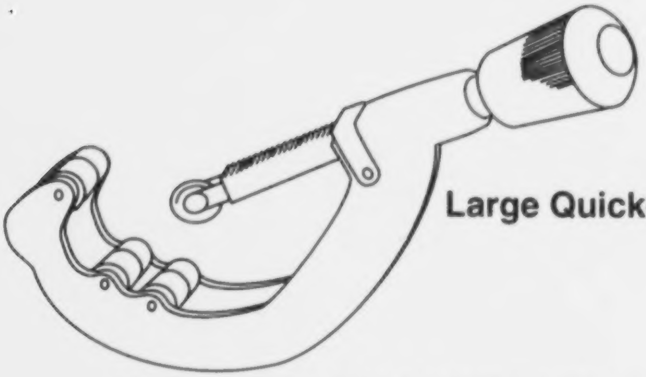
Small Diameter Cutter



Large Cutter



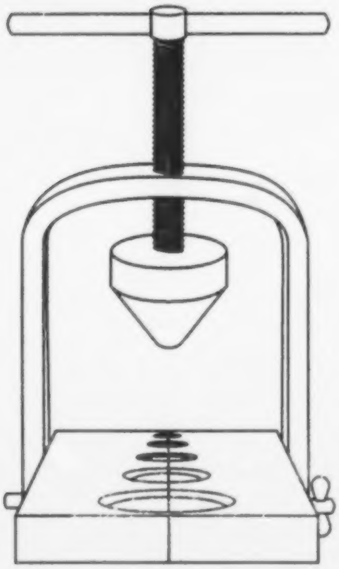
Small Quick-Opening Cutter



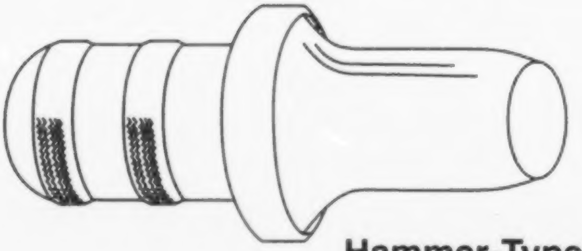
Large Quick-Opening Cutter

TM 2.2

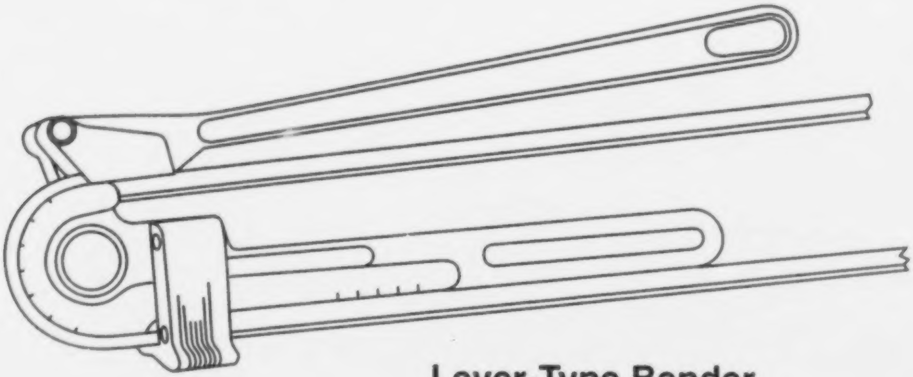
Flaring and Bending Tools



Yoke and Screw Flaring Tool



Hammer-Type Flaring Tool



Lever-Type Bender

Lesson 2: Plumbing Safety

Name ____________________________

Working with Plumbing Safely

Objective: Describe safety concerns associated with plumbing.

Answer the following questions concerning plumbing safety. Describe a situation in which each hazard might become a danger.

1. What is a serious hazard associated with propane torches used for soldering?

2. What is an essential precaution when working with plastic pipe cement?

3. What is the major concern when working in deep trenches?

4. Why should small sections of scrap pipe be picked up immediately?

UNIT VI - PLUMBING

Lesson 3: Pipe Types and Size Requirements

Competency/Objective: Identify pipe types and determine size requirements.

Study Questions

1. **What are the types of pipes and the characteristics of each?**
2. **How are pipes sized?**
3. **How is the pipe size needed to deliver a desired flow rate determined?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit VI.
2. Transparency Masters
   - a) TM 3.1: Plastic Pipe Fittings
   - b) TM 3.2: Copper Pipe Fittings
   - c) TM 3.3: PVC Pipe Size Table
3. Activity Sheets
   - a) AS 3.1: Pipe Usage

UNIT VI - PLUMBING

Lesson 3: Pipe Types and Size Requirements

TEACHING PROCEDURES

A. ***Review***

Lesson 2 described safety practices for working with plumbing. They are important because all agricultural operations require some plumbing. A variety of pipe materials that are easy enough for non-professionals to install exist for use in plumbing systems. This lesson explores the basics of pipe types and sizes.

B. ***Motivation***

1. Collect and display samples of different types and sizes of pipe. Hardware stores or plumbers may have short sections of pipe available that they would be willing to donate.

2. Take a field trip to a local hardware store to observe the different types of pipe available. If possible, have a clerk discuss the different types of pipe.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Discuss the different types of pipe and their characteristics. Use the pipe samples from the motivation or pictures as examples. TMs 3.1 and 3.2 can be used to illustrate some common types of pipe fittings that will be used with these plastic and copper pipes. Hand out AS 3.1 to the class. Point out that as they investigate the types of pipe used, they may see galvanized metal pipe in older structures.

What are the types of pipe and the characteristics of each?

a) Plastic pipe
    1) Most popular plumbing material for agricultural structures
    2) Durable and readily available in various forms and diameters
    3) Less expensive than copper pipe
    4) Easier to work with; requires few specialized tools or skills
    5) Brittle and more easily broken at low temperatures
    6) Crushed more easily
    7) Five basic types
        (a) Polyvinyl Chloride (PVC)
            (1) Common rigid white plastic pipe seen around construction sites
            (2) Generally is either 1 inch or ¾ inch in diameter
            (3) Comes in lengths of 10 to 20 feet
            (4) Used for cold water supply and waste disposal lines
            (5) Not recommended for hot water because of its chemical composition
        (b) Chlorinated Polyvinyl Chloride (CPVC)
            (1) Off-white or cream in color
            (2) Recommended for temperatures up to 180 degrees Fahrenheit
            (3) Most commonly found in ½- to ¾-inch diameters and 10 foot lengths
            (4) Common choice for hot water lines
        (c) Acrylonitrile-Butadiene-Styrene (ABS)
            (1) Hard black plastic pipe used mostly for drain and sewer lines

            (2) Commonly available in sizes ranging from 1¼ inches to 6 inches in diameter and in lengths of 10 to 20 feet
        (d) Polyethylene (PE)
            (1) Flexible black plastic tubing
            (2) Comes in coils from 100 to 300 foot in length
            (3) Available in diameters of ¾ inch to 2 inches
            (4) Cannot withstand heat and so is only useful for handling cold water
            (5) Primarily used for installing underground water service lines
        (e) Polybutylene (PB)
            (1) Flexible plastic pipe, usually gray in color
            (2) Uses with cold or hot water
            (3) Most commonly ⅜ inch or ¼ inch in diameter
            (4) Flexible enough to go around corners or objects without having to be cut and joined
            (5) Have been prone to leaks, especially around fittings

b) Copper pipe
    1) Very durable
    2) Not difficult to work with, but does require more skill and specialized equipment
    3) More expensive than plastic pipe
    4) Available in two forms, hard and soft copper
        (a) Rigid hard copper pipe
        (b) Flexible soft tubing
    5) Available in sizes of ¼ inch to 12 inches in diameter
    6) Generally comes in 20-foot lengths for hard copper and coils varying in lengths from 45 to 100 feet for soft copper
    7) Four weights
        (a) K
            (1) Thickest walls of the four types
            (2) Available in hard and soft copper forms
            (3) Color coded green
            (4) Used for underground supply lines
        (b) L
            (1) Slightly thinner than K
            (2) Available in hard or soft forms
            (3) Color coded blue
            (4) Used above ground, for general interior work
        (c) M
            (1) Slightly thinner than L
            (2) Available in hard form only
            (3) Color coded red
            (4) Commonly used for above ground interior water supply, waste, or drainage lines
        (d) DWV
            (1) Thinnest of the four types of copper pipe
            (2) Available only in the hard form
            (3) Color coded yellow
            (4) Used above ground for drainage, waste, or vent pipes

2. Discuss pipe sizes with the class.

How are pipes sized?

a) All types of pipe are referred to by their diameter.
b) Standard pipe sizes are ½, ¾, 1, 1¼, 1½, 2, 2½, 3, 4, 5, 6, and 8 inches.
c) Pipe sizes are measured to the nearest fraction of an inch.
d) The measurement most often approximates the inside diameter (ID) of small pipes of less than six inches and the outside diameter (OD) on large pipes.

3. Ask students what factors concerning pipes might affect the flow rate. Discuss how to determine the proper pipe size TM 3.3 can be used to demonstrate the use of pipe size tables.

How is the pipe size needed to deliver a desired flow rate determined?

a) For complex construction projects where the pipes must be sized exactly to deliver the desired flow rate
    1) Two pieces of information are required.
        (a) Desired flow rate in gallons per minute
        (b) Amount of resistance due to friction between the water and the surface of the pipe.
    2) Determine the desired flow rate by adding the typical flow rates for different water outlets that will be operating at the same time.
    3) Select a pipe size that will allow the desired flow rate while limiting losses in pressure due to friction to 5 pounds per square inch or less.
b) A less exact method for less complex structures like homes and agricultural buildings
    1) Use pipe size tables to choose the correct pipe size given the pipe system length and the desired flow rate.
    2) Add ten percent to the measured length of the system to make up for losses due to fittings when using the table.

F. *Other Activities*

Ask a plumber or plumbing sales representative to come and speak to the class concerning pipe materials and sizing considerations.

G. *Conclusion*

Plastic and copper pipes are commonly used because they are relatively easy to work with. These materials are available in a variety of forms and sizes that serve many different functions. Many factors can affect the size of the pipes used in a plumbing system. One way that the necessary pipe size can be determined is by looking at the amount of water needed and the amount of friction between the water and the surface of the pipe.

H. *Answers to Activity Sheet*

I. *Answers to Evaluation*

1. c
2. b
3. d
4. a
5. b
6. b
7. d
8. c

9. Answers may include any two of the following: ½, ¾, 1, 1¼, 1½, 2, 2½, 3, 4, 5, 6, and 8 inches.

10. 1½ inch pipe

UNIT VI - PLUMBING Name ______________________________

Lesson 3: Pipe Types and Size Requirements Date ______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. How many common forms of plastic pipe are available for plumbing?

   a. Three
   b. Four
   c. Five
   d. Six

2. The plastic pipe suitable for hot water is called:

   a. CPV.
   b. CPVC.
   c. PVC.
   d. ABS.

3. When sizing pipe, a size must be selected that will allow the desired flow rate while limiting losses to:

   a. 2 pounds per square inch or less.
   b. 3 pounds per square inch or less.
   c. 4 pounds per square inch or less.
   d. 5 pounds per square inch or less.

4. Which is the thinnest form of commercial copper pipe?

   a. DWV
   b. M
   c. L
   d. K

5. Pipe sizes are referred to by their:

   a. Radius.
   b. Diameter.
   c. Length.
   d. Volume.

6. Which type of copper pipe is used for general interior work?

   a. K
   b. L
   c. M
   d. DWV

7. The hard black plastic pipe mostly used for drain lines is:

   a. PVC.
   b. PE.
   c. CPVC.
   d. ABS.

8. What is the plastic tubing used for underground water service lines?

   a. CPVC
   b. PVC
   c. PE
   d. ABS

Complete the following short answer questions.

9. What are two standard pipe sizes?

   a.

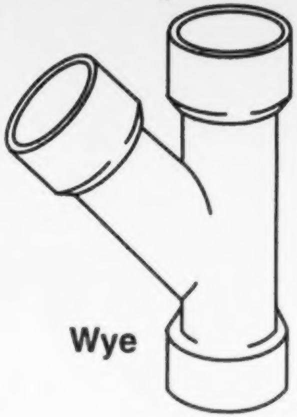
   b.

10. What size of PVC pipe should be used for a pipe system that is 250 feet in length with a flow rate of 10 gallons per minute?

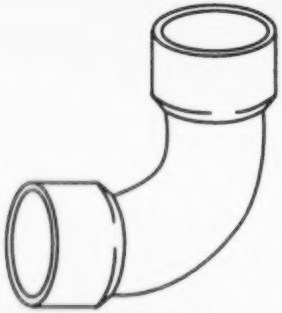
Distance in Feet*	Flow Rate (Gallons Per Minute)						
	2	3	5	7.5	10	15	20
Up to 25	½	½	¾	¾	1	1	1
50	¾	¾	¾	1	1	1¼	1¼
75	¾	¾	1	1	1	1¼	1½
100	¾	¾	1	1	1	1¼	1½
150	¾	¾	1	1	1¼	1½	1½
200	¾	1	1	1¼	1½	1½	2
300	¾	1	1	1¼	1½	2	2
400	1	1	1¼	1½	1½	2	2
500	1	1	1¼	1½	2	2	2

*Add 10 percent to the measured length to account for losses due to pipe fittings.

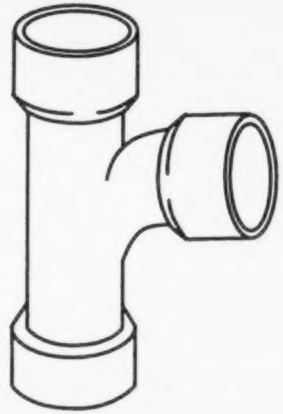
Plastic Pipe Fittings



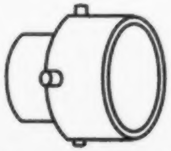
Wye



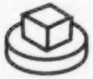
90° Elbow



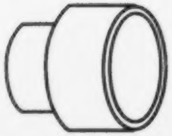
Tee



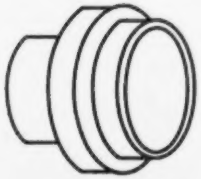
Cleanout Adapter



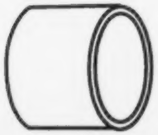
Plug



Reducing Coupling

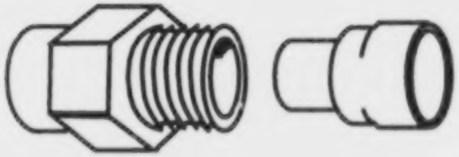


Bushing

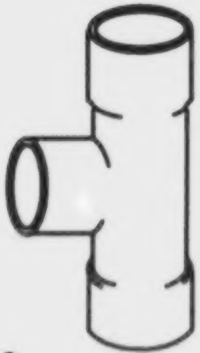


Coupling

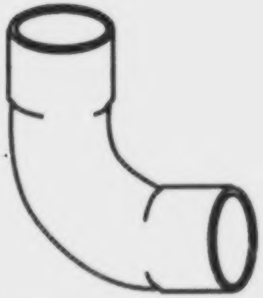
Copper Pipe Fittings



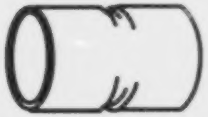
Adapters



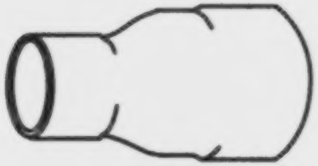
Tee



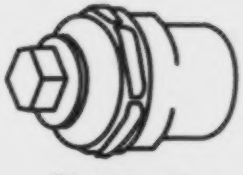
90° Elbow



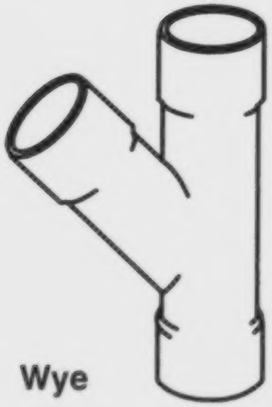
Coupling



Reducing Coupling



Cleanout with Plug



Wye

Agricultural Structures, VI-37

TM 3.2

PVC Pipe Size Table

Distance in Feet*	Flow Rate (Gallons Per Minute)						
	2	3	5	7.5	10	15	20
Up to 25	½	½	¾	¾	1	1	1
50	¾	¾	¾	1	1	1¼	1¼
75	¾	¾	1	1	1	1¼	1½
100	¾	¾	1	1	1	1¼	1½
150	¾	¾	1	1	1¼	1½	1½
200	¾	1	1	1¼	1½	1½	2
300	¾	1	1	1¼	1½	2	2
400	1	1	1¼	1½	1½	2	2
500	1	1	1¼	1½	2	2	2
600	1	1	1¼	1½	2	2	2
700	1	1¼	1¼	1½	2	2	2½
800	1	1¼	1½	1½	2	2	2½
900	1	1¼	1½	2	2	2½	2½
1,000	1	1¼	1½	2	2	2½	2½
1,500	1¼	1¼	1½	2	2	2½	2½
2,000	1¼	1½	2	2	2½	2½	3
3,000	1¼	1½	2	2	2½	3	3

*Add 10 percent to the measured length to account for losses due to pipe fittings.

AS 3.1

Lesson 3: Pipe Types and Size Requirements Name ______________________

Pipe Usage

Objective: Identify where different types of pipes are used.

Look at the pipes in various structures, including your house, agricultural buildings, and school, as well as any other buildings to which you have access. Fill out the chart below, indicating the location of the pipes, what type of pipe was used, and why that type of pipe was chosen for that location. Then answer the questions about your observations.

Location	Type of Pipe	Reasons for Use

Lesson 4: Measuring, Cutting, and Connecting Pipes

***Competency/Objective*:** Measure, cut, and connect pipes and tubing.

Study Questions

1. **What factors must be considered before proper measurement of a pipe system can be accomplished?**
2. **How are different types of pipe cut properly?**
3. **What methods are available to join different types of pipe?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit VI.
2. Activity Sheet
    - a) AS 4.1: Cutting and Joining Plastic Pipe
3. Job Sheet
    - a) JS 4.1: Sweating Copper Pipe

Lesson 4: Measuring, Cutting, and Connecting Pipes

Teaching Procedures

A. ***Review***

Lesson 3 described the types and sizes of pipe and fittings used for plumbing and how they are sized to deliver a certain flow rate. After a particular type and size of pipe is chosen, it must be installed. Measuring, cutting, and joining pipe is an essential part of installing plumbing lines.

B. ***Motivation***

Have students observe the pipes located in the agriculture facility or elsewhere in the school. Ask them how they would cut and join the pipes for that particular application.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. With a metal tape measure or folding ruler, demonstrate how to measure by measuring around a room to find the total distance. Lay out pipes to fit a certain distance and then show how much attaching fittings to the pipes increases the length.

   What factors must be considered before proper measurement of a pipe system can be accomplished?

   a) Distance from the water source to the desired outlet along the exact path that the pipe will take
   b) Length of the pipe being installed
   c) Fittings used to join the sections of pipe, since they increase the length of the system
      1) The amount of increase is dependent on the size of the fittings as well as any angles made by the fittings.
      2) The length of the pipes may have to be adjusted to account for the fittings.

2. If possible, demonstrate how to cut pipe using a hacksaw or pipe cutter. Let the class examine the cut before and after smoothing it with sandpaper or some other tool, such as a knife or file. Cut some copper pipe and or tubing for the class and let them examine the joint before and after smoothing the cut with a file. Describe the process for using the different cutting tools.

   How are different types of pipe cut properly?

   a) Carefully measure the pipes with a tape measure or folding ruler.
      1) Make an allowance for the fittings; add the length to which the pipe will slide or screw into the fitting to the length that will run between fittings.
      2) With a pencil, mark the point where the pipe should be cut.
      3) The marking should extend all the way around the pipe.
      4) Measurements should be made to the nearest 1/32 of an inch.
   b) Cut the pipe.
      1) Use a wheel-type cutter for copper pipe.
         (a) Open the cutter by turning the handle until the pipe will fit between the wheel and roller.
         (b) Place the pipe in the base of the cutter and turn the handle until the pipe touches the cutter wheel.

            (c) Position the wheel on the point where the pipe is to be cut.
            (d) Turn the handle to press the wheel into the pipe.
            (e) Rotate the tool around the pipe once.
            (f) Tighten the handle and rotate the tool again.
            (g) Repeat this process until the pipe is cut.
        2) Use a hacksaw for plastic pipe.
            (a) If possible, place the pipe in a vise to hold it still.
            (b) Position the hacksaw blade on the mark for cutting.
            (c) Pull the hacksaw backwards, placing no pressure on the pipe.
            (d) Bring the blade forward with pressure exerted to cut into the pipe.
            (e) Hold the saw at a 90-degree angle to the pipe, resulting in a square cut.
            (f) Repeat this process until the pipe is sawn through completely.
    c) Smooth any burrs and ridges left on the inside or outside of the pipe from cutting.
        1) With copper pipe, use a small file, sandpaper, or a special reaming tool.
        2) Use sandpaper or a knife for plastic pipe.

3. Discuss the different methods of joining pipe. If time and materials are available, demonstrate joining plastic pipes and fittings with cement. Let the students try to pull the joint apart to show how solid they can be. Have students complete AS 4.1 and JS 4.1.

What methods are available to join different types of pipe?

a) Cements for plastic pipe
    1) The end of the pipe and the fitting must be smooth and clean; a chemical cleaner is the best way to clean this material.
    2) Once the fitting and pipe ends are clean, they are covered with an even coating of cement on the pipe and fitting socket.
    3) The cement usually acts quickly, so the pieces need to be joined together immediately and firmly.
    4) The pipe should be given a quarter turn to make sure it is seated securely.
    5) A solid and permanent joint will be created after the pipe and fitting are held together ten seconds to a minute.
    6) A line of cement should appear all the way around the joint, indicating that enough cement was used.
    7) The directions and recommendations for cements should always be read before they are used.
b) Soldering for copper pipe
    1) The end of the pipe and the fitting must be clean; very fine sandpaper or emery cloth works well.
    2) The use of soldering material, which looks like heavy wire, is enhanced by flux; flux may need to be placed on the joint before soldering.
    3) Since different kinds of solder have different compositions and recommended uses, the manufacturer's instructions should be read before the material is used.
    4) The fitting is placed on the pipe or tubing.
    5) A propane torch is used to heat first the pipe and then the fitting until the solder melts [illegible] touching the joint.
    6) The solder is fed to the rim of the fitting and is drawn into the joint.
    7) The solder is applied around the joint until it is found around the entire rim of the fitting.
    8) The excess solder is wiped away while the pipe and fitting are still hot.
c) Flare joints for copper tubing
    1) A flare nut is placed on the tubing.
    2) The pipe is flared using some type of flaring tool; one common type of flaring tool is a yoke and screw flaring tool.
    3) The tubing is placed in the correctly sized opening of a flaring block and secured in position, with the end of the tubing extending above the block about ⅓ the depth of the block chamfer.

4) The yoke of the flaring tool is placed over the block, with the compression cone centered over the tubing.
5) The screw is tightened to form the flare between the block and the cone.
6) The screw should not be turned too far, since the tubing may split.
7) When the flare is finished, the fit of the flare is checked to the seat of the flare nut.
8) The fitting is then placed against the flare.
9) The nut is tightened to hold it in place.

F. *Other Activities*

1. Have the class figure how much plumbing material would be needed to span a given area. Specify the length of the pipes used and the types of fittings required.

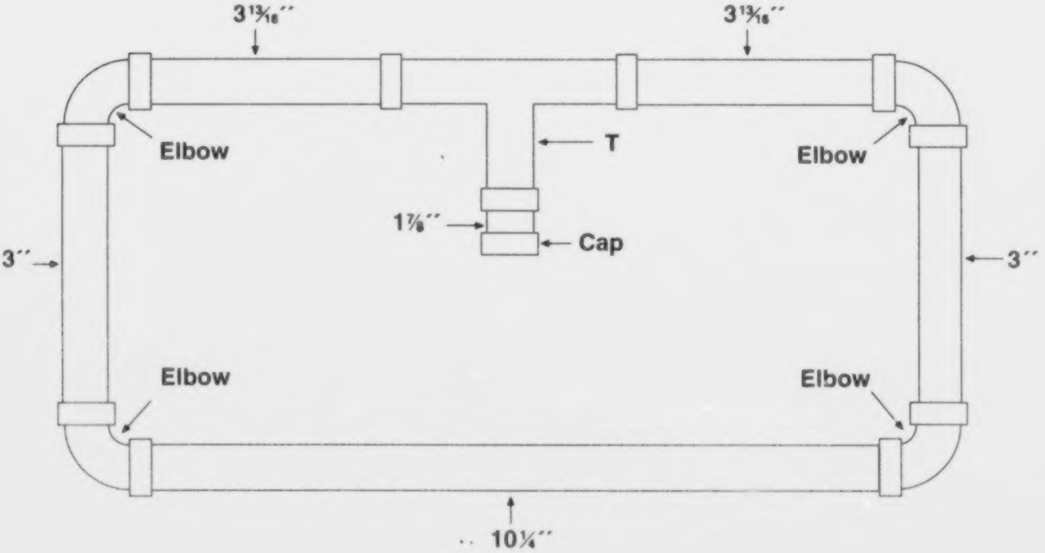
2. Have the students measure and cut some pipe material. Check the length of the pipe for accuracy.

G. *Conclusion*

Precise measurements are necessary to determine the lengths of the materials in a plumbing system. Pipes are then cut to the appropriate length. When pipe has been cut, the pipes and fittings are joined. The goal is to produce a solid, watertight joint using pipes and fittings that have been cut to provide plumbing that is the proper length for installation.

H. *Answers to Activity Sheet*

To achieve the correct dimensions, students will have to cut the pipe accurately. The correct lengths for the different pieces of pipe are shown below.



1. Answers will vary.
2. Answers will vary.
3. The same skills are used in preparing and constructing PVC pipe projects in structures.

I. *Answers to Evaluation*

1. c
2. b
3. d
4. The distance from the water source to the desired outlet along the exact path that the pipe will take, the length of the pipe being installed, and the fittings used to join the sections of pipe
5. That enough cement was used
6. Because different kinds of solder have different compositions and recommended uses

UNIT VI - PLUMBING

Lesson 4: Measuring, Cutting, and Connecting Pipes

Name ______________________________

Date ______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Because accurate measurements are very important, measurements should be made to the nearest __________ of an inch.

   a. 1/8 of an inch
   b. 1/16 of an inch
   c. 1/32 of an inch
   d. 1/64 of an inch

2. A plastic pipe and fitting should be held together for at least ________________ seconds to be sure the joint will hold.

   a. 5
   b. 10
   c. 15
   d. 20

3. When cutting pipe with a hacksaw, the saw should be held at a __________________ angle to the pipe to produce a square cut.

   a. 30-degree
   b. 45-degree
   c. 60-degree
   d. 90-degree

Complete the following short answer questions.

4. What three factors should be considered when measuring pipe?

   a.

   b.

   c.

5. What does a ring of cement around a joint indicate?

6. Why should the manufacturer's instructions be read before soldering material is used to join pipes?

Lesson 4: Measuring, Cutting, and Connecting Pipes Name ______________________________

Cutting and Joining Plastic Pipe

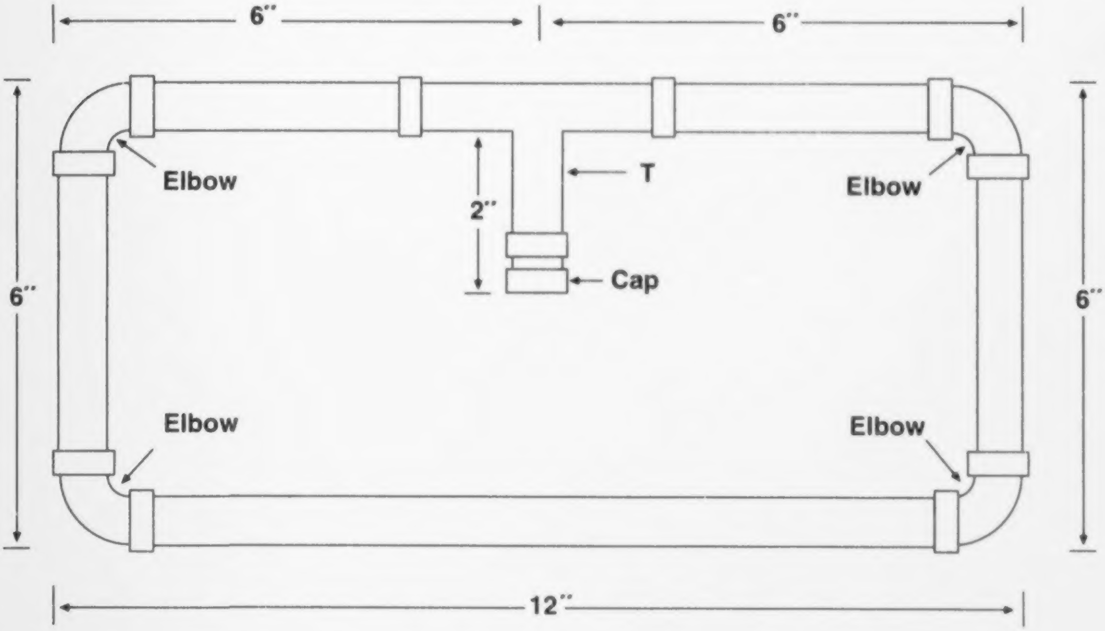
Objective: Cut and join plastic pipe.

Materials and Equipment:

1" PVC pipe, 4 feet in length
4 1-inch 90-degree PVC elbows
1 1-inch PVC T
1 1-inch PVC cap
Tape measure
Hacksaw
PVC primer and glue (optional)
Sandpaper

Procedure:

Using the diagram below, construct the PVC apparatus shown. Measure each piece carefully because you do not have much extra material. Once you have the pieces of pipe cut, either glue or stick the pieces together, depending on your instructor's directions.



Key Questions:

1. Does your project have the correct dimensions? If not, why not?

2. What changes would you make in your procedure in constructing this project?

3. How could these skills be used in real world applications?

Lesson 4: Measuring, Cutting, and Connecting Pipes Name ____________________

Sweating Copper Pipe

Objective: Join a copper pipe and fitting.

Materials and Equipment:

1 1" copper pipe, 4 inches in length
1 1" cap
Flux
Brush
Propane torch
Stationary vise
Steel wool or sandpaper

Procedure:

1. Place the pipe in the stationary vise.
2. Apply flux to the inside of the cap and the outside of the pipe using the brush.
3. Join the cap and pipe.
4. Begin heating the cap as shown in Figure 1.1.
5. When the flux starts to bubble, add a small amount of solder to the rim of the fitting on the opposite side of the fitting from the heat source.
6. After the solder is drawn into and around the joint and seals the cap, use the steel wool or sandpaper to clean off the excess solder.
7. Allow the pipe to cool.

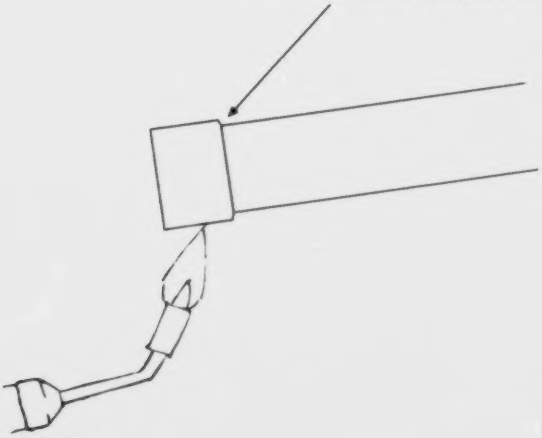


Figure 1.1

UNIT VI - PLUMBING

Lesson 5: Protecting Water Pipes from Freezing

Competency/Objective: Identify methods of protecting water pipes against freezing.

Study Questions

1. **In respect to pipe freezing, what factors must be considered before installing pipe?**
2. **What different methods are available to prevent pipes from freezing?**
3. **What methods are available to thaw frozen pipes?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit VI.
2. Transparency Master
    a) TM 5.1: Electric Heat Tape
3. Activity Sheet
    a) AS 5.1: Water Pipes and Freezing Temperatures

Lesson 5: Protecting Water Pipes From Freezing

TEACHING PROCEDURES

A. ***Review***

Lesson 4 described methods of measuring, cutting, and joining pipe for installation. An important factor to consider when installing pipes is protecting them from freezing. Designing a plumbing system to prevent freezing and providing sufficient protection for pipes are necessary because of the potential cost of damage from pipes that have split and burst. If pipes do freeze, several methods are available to heat and thaw the frozen sections of pipe.

B. ***Motivation***

Cap one end of a short section of plastic pipe, fill it with water, and cap the other end. Place this in a very cold freezer or on dry ice for a few hours. When the water in the pipe has frozen, show it to the class. It likely will have bulged and split from the expansion of the water as it turned to ice. (If time allows, students may perform this experiment themselves.)

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Discuss the consequences of frozen pipes, referring back to the pipe used for the motivation. Explain that sections of pipe damaged due to freezing must be replaced even if water lines have to be dug up. Discuss factors to consider when installing pipe.

   In respect to pipe freezing, what factors must be considered before installing pipe?

   a) Running water lines underground below the frost line
      1) The average frost line in Missouri ranges is 3 feet.
      2) Pipes should be below the frost line.
      3) Most people install their pipes a foot below the frost line to help prevent freezing.
   b) Design of the plumbing system
      1) Designing the system so that pipes are placed in interior rather than outside walls can protect them.
      2) Insulation should be used around pipes placed near exterior walls.
         (a) R factor of 6.5 to 8
         (b) Carefully wrapped, with the ends butted together tightly and joined with tape
      3) Frost-free faucets should be used outdoors.
      4) If pipe is installed in an area subject to freezing, a drain valve should be added.

2. Discuss effective practices for preventing pipes from freezing. If possible, show a sample of electric tape and pipe insulation to the class.

   What different methods are available to prevent pipes from freezing?

   a) Wrapping exposed pipe in waterproof insulation
   b) Protecting exposed pipe from direct winds
   c) Supplying at least minimal heat to the inside of the structure using any appropriate heating system
   d) Using electric heat tape

        1) The heat tape is placed along the pipe, which is then wrapped in insulation to hold the heat close to the pipe.
        2) The tape carries an electrical current through it to supply heat.
        3) Heat tape can be wired either with a timer set to turn it on and off at certain times or with a thermostat that activates the tape at a designated temperature.
    e) Allowing water to run continuously
        1) If water pressure begins to drop, the line should be opened a little so that the water runs continuously.
        2) If the pressure returns to normal, the water should be allowed to drip or trickle from the faucet until the temperature rises to a safe point.

3. Ask students how they would thaw a pipe once it had frozen. Discuss the following different methods of thawing the pipe. Have students complete AS 5.1.

What methods are available to thaw frozen pipes?

- a) Torches used by professional plumbers
    - 1) If the flame comes in contact with combustible material, a fire can result.
    - 2) Heating the pipes in one spot too quickly can cause the water to boil, creating enough pressure to cause the pipes to explode.
    - 3) A flame should never be applied directly to a plastic pipe.
- b) Electric heaters, hair dryers, heating pads, and electric blankets - should only be used after evaluating if any danger of electrical shock exists
- c) Placing embers or charcoal briquettes in an appropriate container near frozen pipes for exterior pipes

F. *Other Activities*

Ask a plumber to come and speak to the class about methods they have found effective for preventing pipes from freezing and thawing frozen pipes.

G. *Conclusion*

Every attempt should be made to protect pipes from freezing. Placing lines below the frost line and providing insulation or other protection for any pipe that is not buried will greatly increase the odds of avoiding frozen pipes. If all efforts to prevent freezing have failed, the solution to frozen pipes is to raise the temperature enough for them to thaw by whatever safe and practical means are available.

H. *Answers to Activity Sheet*

I. *Answers to Evaluation*

1. a
2. b

3. The heat tape is placed along the pipe, which is then wrapped in insulation to hold the heat close to the pipe.

4. Fire and exploding pipes caused by the pressure from boiling water

5. Answers may include any two of the following: electric heater, hair dryer, heating pad, and electric blanket.

6. Drain valve

UNIT VI - PLUMBING Name ______________________

Lesson 5: Protecting Water Pipes from Freezing Date ______________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Exposed pipe should be:

   a. Wrapped with waterproof insulation.
   b. Covered with an electric blanket.
   c. Buried in dirt.
   d. Wrapped in duct tape.

2. If the water pressure begins to drop, what should be done to prevent the pipe from freezing?

   a. The outlet should be turned off.
   b. The water should be allowed to run continuously.
   c. Water to the entire plumbing system should be shut off.
   d. The pipe should be heated using a propane torch.

Complete the following short answer questions.

3. How is electric heat tape used to keep pipes from freezing?

4. What are two problems that may occur when using a torch to thaw copper pipes?

   a.

   b.

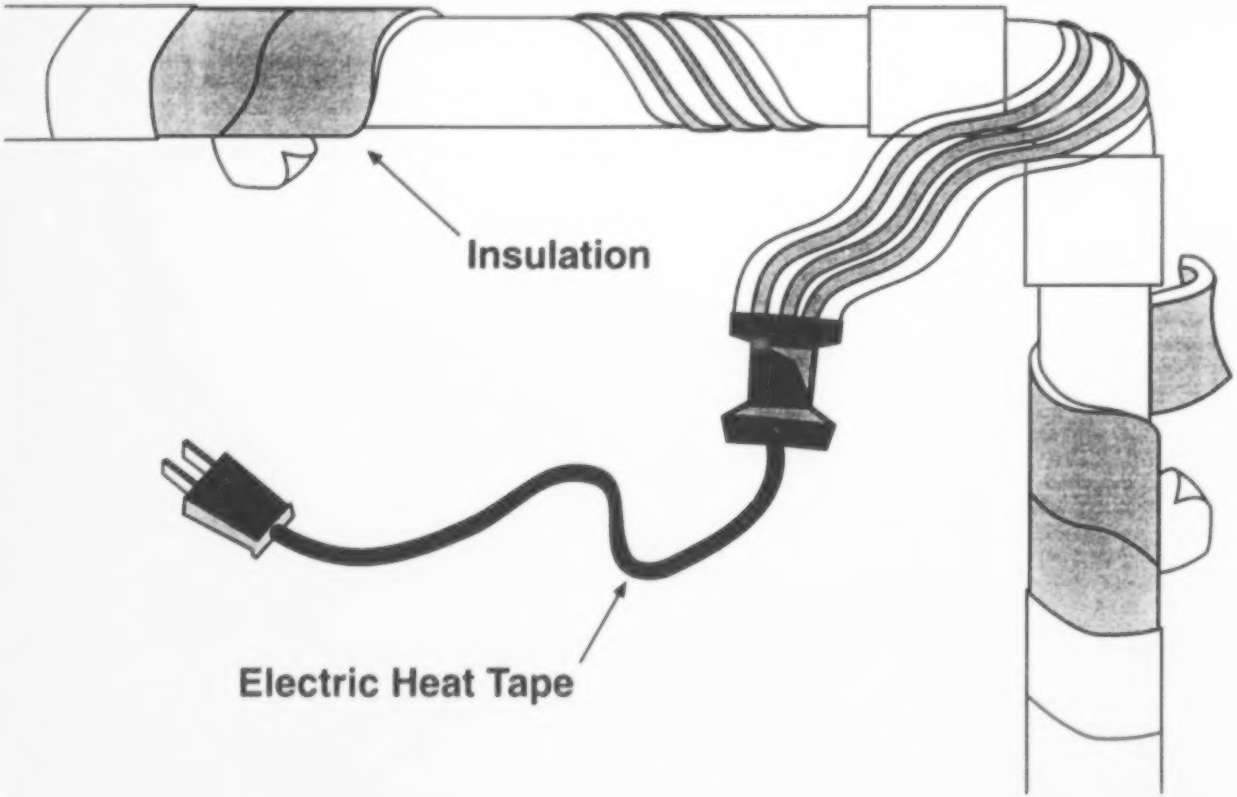
5. What are two electric devices that can be used to thaw frozen pipes?

   a.

   b.

6. What special fixture should be added if pipe is installed in an area subject to freezing?

Electric Heat Tape


Insulation
Electric Heat Tape

Agricultural Structures, VI-61

TM 5.1

Lesson 5: Protecting Water Pipes from Freezing Name ______________________________

Water Pipes and Freezing Temperatures

Objective: Describe common methods for preventing freezing in water lines and for thawing pipes.

Using the questions below, interview three different homeowners or owners of agricultural operations about their experiences with frozen water lines. Record their answers here or on another sheet of paper if more space is needed. Be prepared to discuss the answers with the class.

1. Have any of your water lines ever frozen?

2. If not, what measures were taken that prevented freezing?

3. If so, where and why did the lines freeze?

4. Did any damage occur to the plumbing system? If so, what was done to repair the damage?

5. What action was taken to thaw the pipe?

UNIT VII - FENCING

Lesson 1: Fencing Basics

Competency/Objective: Discuss the terminology, dangers, and safety practices associated with building fences.

Study Questions

1. **What is a legal fence?**
2. **What are the common tools used in building fences and safety measures for their uses?**
3. **What are the safety measures used in putting up a fence?**

References

1. *Agricultural Structures (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit VII.
2. Activity Sheet
    - a) AS 1.1: Building Legal Fences

Lesson 1: Fencing Basics

TEACHING PROCEDURES

A. ***Introduction***

Suitable fencing is necessary for many types of agricultural enterprises. In this unit, a discussion of some of the fencing options available and how they may be erected will be presented. This lesson describes some fencing basics. Before constructing a fence, an understanding of what constitutes a legal fence is required to avoid being liable for damages if livestock do get out. Also, because working with fences can be dangerous, taking precautions is important for safety's sake.

B. ***Motivation***

Discuss the fence types and their uses in your area. If possible, show some pictures of well-built fences and fences that would not meet the definition of a legal fence.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Ask students to provide examples of what kind of damage can occur if livestock get out of a pasture or lot. Discuss the legal definitions of a fence. Have students complete AS 1.1.

   NOTE: Because fencing laws vary, check the local regulations to find out the definition of a legal fence in a particular area. Reviewing the laws concerning fencing each time this lesson is taught may also be helpful to make sure that the regulations have not changed.

   What is a legal fence?

   a) General law
      1) Hedges are at least 4 feet high.
      2) Fences composed of posts and rails, post and palings, posts and wire, posts and boards, or palisades are at least 4½ feet high with posts firmly in the ground not more than 8 feet apart.
      3) Fences consisting of woven wire, wire netting, or wire mesh are at least 4½ feet high with posts not more than 16 feet apart.
      4) Other fence structures satisfying the definition of a lawful fence are described, including worm (rail) fences, turf fences, and stone or brick fences.
      5) All fences should be constructed to resist horses, cattle, swine, and similar stock.
   b) Fence and Enclosure Act of 1963
      1) A fence with not fewer than four boards per 4 feet of height, each board to be spaced no farther apart than twice their width and to be fastened to posts not more than 12 feet apart with one stay.
      2) A fence of four barbed wires supported by posts not more than 15 feet apart with one stay or 12 feet apart with no stays.
      3) Any fence that is at least equivalent to the types of fences in the other categories.

2. Ask students to list some tools that might be used for fencing. Describe the safety practices associated with their use.

   What are the common tools used in building fences and safety measures for their use?

- a) **Basic tools**
    - 1) **Hand-operated post hole digger**
    - 2) **Power-driven post hole digger (sometimes called an auger)**
    - 3) **Metal rod for packing earth around posts**
    - 4) **Hammer**
    - 5) **Tape measure**
    - 6) **Fencing pliers**
    - 7) **Fence stretchers**
    - 8) **Hand ax**
    - 9) **Chain saw**
    - 10) **Metal post driver**
    - 11) **Post maul for driving wooden posts**
    - 12) **Roll of nylon string to help lay out straight lines**
    - 13) **Level to help assure that posts are set straight**
- b) Protective clothing
    - 1) Steel-toed boots
    - 2) Heavy pants
    - 3) Gloves
    - 4) Eye protection
- c) Safety measures
    - 1) Hand-operated post hole diggers
        - (a) The target area for digging should be clear and free of large rocks.
        - (b) Maintaining good posture while operating this tool will help reduce back strain or injury.
    - 2) Power-driven post hole diggers
        - (a) Follow the manufacturer's recommendations.
        - (b) Keeping any loose clothing away from the auger can help prevent serious injury, because it can easily mangle a person's arms or legs if clothing gets caught in the auger as it twists.
        - (c) Hearing and eye protection should be used.
    - 3) Metal rods
        - (a) Protective glasses can prevent injury to the eyes.
        - (b) Gloves and steel-toed boots can help avoid injury to the hands and feet.
    - 4) Metal post drivers
        - (a) Good posture and control while lifting the post driver can help avoid back injury.
        - (b) Gloves will help [illegible]ers.
    - 5) Post maul
        - (a) Make sure that everyone working in the same area is out of striking distance.
        - (b) Gloves should be worn to protect the hands.
        - (c) Eye protection should be worn to prevent injuries from stray flying material.
    - 6) Hand ax - Safety glasses, gloves, and steel-toed boots are needed for safety.
    - 7) Chain saw - Hearing protection, eye protection, gloves, and steel-toed boots will increase safety.
    - 8) Fence stretchers - The tool should be used with caution, because wire that has been stretched too tightly may [illegible]

3. Discuss other safety measures that can be taken when constructing a fence.

What are the safety measures used in putting up a fence?

- a) Protective clothing and safety accessories should be used; a hat and a shirt with long sleeves may provide additional protection.
- b) If possible, fence construction should not involve working alone in an isolated area, since help may be necessary if an injury occurs.
- c) The tools used for construction of the fence should only be used as designed and recommended by the manufacturer.

d) Fence construction may involve heavy lifting, so proper lifting techniques should be used.
    1) Keep the back straight and use the leg muscles to help move the weight.
    2) Hold heavy loads close to the body to help reduce strain.

e) Unexpected hazards such as wasps, bees, snakes, and plants such as poison ivy are also to be considered and avoided if possible.

f) Caution should be used when working with wire, which commonly causes cuts.

g) Overstretching may occur, causing the wire to break and whip back against or around the person stretching it or someone else; wearing gloves and eye protection is a must.

F. *Other Activities*

Have students collect pictures of good and bad fences to add to the collection displayed in the motivation.

G. *Conclusion*

A good fence is required for livestock, to ensure their safety and to prevent property damage. Fences should meet the definition of a legal fence to avoid liability if livestock do cause damage. Using basic fencing tools safely, wearing protective clothing, and taking precautions can help make building a fence safer.

H. *Answers to Activity Sheet*

Barbed wire:

Number of posts - 220
Length of barbed wire - 10,560 feet

Woven wire:

Number of posts - 168
Length of woven wire - 2,640 feet

Boards:

Number of posts - 332
Number of 2" × 6" boards - 1,328 boards

1. Posts and boards
2. Posts and boards
3. Barbed wire, because it is cheaper and easier to construct

I. *Answers to Evaluation*

1. b
2. c
3. a
4. d
5. b

6. Answers may include any two of the following: steel-toed boots, heavy pants, gloves, and eye protection.

7. Because the augur can mangle a person's arms or legs if clothing gets caught in it as it twists.

UNIT VII - FENCING

Name ______________________________

Lesson 1: Fencing Basics

Date ______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is a provision of the general statute defining a legal fence?

   a. A fence has four boards per 4 feet of height.
   b. Fences consisting of woven wire are 4½ feet high.
   c. Barbed wire fences are 3 feet high.
   d. A wire mesh fence has posts 18 feet apart.

2. An important safety consideration when using a post maul is:

   a. The number of swings needed.
   b. The weight of the tool.
   c The position of anyone else in the area.
   d. The material of the handle.

3. Overstretching fence wire can cause the wire to:

   a. Break.
   b. Weaken.
   c. Knot.
   d. Tighten.

4. Under the Fence and Enclosure Act of 1963, a barbed wire fence should have:

   a. 1 wire.
   b. 2 wires.
   c. 3 wires.
   d. 4 wires.

5. Caution should be used when working with wire, because it commonly produces what type of injury?

   a. Bruises
   b. Cuts
   c. Scrapes
   d. Wire burns

Complete the following short answer questions.

6. What are two items of protective clothing that should be worn when building fences?

   a.

   b.

7. Why is keeping loose clothing away from an auger important?

Lesson 1: Fencing Basics Name ____________________________

Building Legal Fences

Objective: Understand fencing laws that affect agricultural enterprises.

For this activity, imagine that you are a local fencing contractor. A customer has contacted you, asking for a list of the materials needed to build a fence around a small square field. The total length of the fence will be ½ mile. The fence must comply with the state laws for legal fences, which in your county consists of the Fence and Enclosure Act. The customer has not decided whether to use barbed wire, woven wire, or posts and 2" × 6" boards. Develop a list of the materials needed to build each type of fence. The posts will be the same diameter and length for each type of fence. Then answer the questions below.

Barbed wire:

Number of posts, 12 feet apart __________

Total length of the barbed wire __________

Woven wire:

Number of posts, 16 feet apart __________

Total length of the woven wire __________

Boards:

Number of posts, 8 feet apart __________

Number of 2" × 6" boards, 8 feet in length __________

1. Which type of fence will require the largest number of posts?

2. Which fence would probably be the most expensive?

3. Considering the three types of fences discussed, which type of fence do you think is most commonly used on agricultural operations? Why?

UNIT VII - FENCING

Lesson 2: Setting and Bracing Posts

***Competency/Objective*:** Describe how to set and brace wood and steel posts.

Study Questions

1. **What are the materials and tools needed for installing wood posts and braces?**
2. **Where are wood and steel anchor-and-brace assemblies located?**
3. **How are assemblies and brace wire installed?**
4. **How are the wood line posts installed?**
5. **What tools are needed for installing steel posts and braces?**
6. **How are steel post-and-brace assemblies installed?**
7. **How are steel line posts installed?**
8. **What are the factors to consider when installing a gate?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit VII.
2. Transparency Masters
   - a) TM 2.1: Anchor-and-Brace Assemblies
   - b) TM 2.2: H-Brace
   - c) TM 2.3: Metal Corner Post and Braces
3. Activity Sheet
   - a) AS 2.1: Constructing Model Brace Assemblies

Lesson 2: Setting and Bracing Posts

TEACHING PROCEDURES

A. ***Review***

Lesson 1 discussed the tools used to build fences and how to build them safely. Building fences is a labor intensive process. Constructing a fence correctly is better than doing a poor job and having to perform excessive maintenance and repairs. This lesson describes how to install anchor-and-brace assemblies and line posts for wood and steel posts.

B. ***Motivation***

Ask students whether the fences they are familiar with use wood or steel posts or some combination of the two. Ask students why they think the different kinds of posts are used for those fences.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Ask students to describe the tools needed to install braces and wood posts. Discuss the different tools. If possible, show students a sample wood post and brace.

What are the materials and tools needed for installing wood posts and braces?

a) Materials
  1) Wood corner posts
    (a) Chemically treated to resist rotting
    (b) 6 or more inches in diameter
    (c) 8 feet or more in length
  2) Wood line posts
    (a) Chemically treated
    (b) 2½ inches to 6 inches in diameter, with a diameter of 5 inches preferred
    (c) 5½ to 8 feet in length
  3) Wood brace poles
  4) Large nails, such as 16d tempered ring shank pole barn nails
  5) 12½ gauge high tensile smooth wire for wire braces
  6) Staples
b) Tools
  1) Axe
  2) Wheelbarrow
  3) Chain saw
  4) Heavy equipment
  5) Post hole digger
  6) Shovel
  7) Hoe
  8) Tape measure 100 feet or more in length
  9) Level

2. Discuss where anchor-and-brace assemblies are located along the fence line.

Where are wood and steel anchor-and-brace assemblies located?

- a) Fence corners
- b) At points along the fence line to compensate for the effect of stresses exerted on the fence
    - 1) Type of fence
    - 2) Topography of the ground
    - 3) Type of ground
    - 4) Length of the fence run
    - 5) Bends in the fence line

3. Describe the process for installing the most common type of assembly, the H-brace. TM 2.1 can be used to illustrate other types of assemblies. TM 2.2 shows a finished H-brace. Hand out AS 2.1.

How are assemblies and brace wire installed?

- a) Set the posts in place.
    - 1) Place the end or corner post first.
    - 2) Put the second brace post in place in line with the first at the desired distance.
        - (a) A longer brace pole will provide more structural strength.
        - (b) The industry standard is 8 feet in length, but when a single H-brace is needed, using a 10- to 12-foot brace is preferable.
- b) Form a notch for the brace pole in each post.
    - 1) The notches should be perpendicular to the fence line.
    - 2) A good height for the bottom edge of the brace pole is 36 to 42 inches.
    - 3) The height should be determined by the spacing of the fence wires, so the brace does not interfere with wire placement.
- c) Install the twist wire.
    - 1) Wrap the wire twice completely around each of the posts.
    - 2) The direction of the fence pull will determine the placement of the twist wire.
    - 3) Loosely staple the twist wire low on the brace post farthest from the longer stretch of fence and just above the brace on the post next to the length of fence being braced.
    - 4) Remove as much slack as possible from the twist wire by pulling on both ends.
    - 5) Splice the wires together.
- d) Nail the ends of the brace pole to the posts using the 16d nails ring shank nails; four nails are used at each end, one on top, one on each side, and one on the bottom.
- e) Insert a twist stick between the wires.
    - 1) The stick may be a 1-inch [illegible] rod, or a short section of 2" × 4" or 2" × 2".
    - 2) It should be a minimum of 20 inches in length.
- f) Twist the wires so that when the assembly is finished the stick will be pulled against the brace pole on the opposite side from where the wire is attached.
    - 1) The structure should begin to move in the opposite direction from the pull of the fence.
    - 2) A good rule of thumb is to move the end post approximately ½ to ¾ of an inch out of plumb away from the direction of pull.
- g) Attach the twist stick to the brace pole by drilling a ¼-inch hole through the twist stick in line with the brace and then driving a 16d galvanized nail through the stick and into the pole.

4. Discuss the procedures used to install wood line posts.

How are wood line posts installed?

- a) Lay out the fence line.
    - 1) One person stands behind a corner post and another person moves down the fence line toward the next corner post holding a movable post, or sighting pole.
    - 2) The person at the corner post directs him or her to a position that lines up the corner post, the post being held, and the next reference point.

        3) The spot is marked for reference in aligning the posts.
    b) Measure off the line post spacing.
        1) The placement is determined by the type of fence, the amount of pressure that will be placed on the fence by livestock, dips and rises in the ground, and whether steel, fiberglass, or other types of posts are also placed in the fence line.
        2) For field fencing, line posts are commonly 14 to 20 feet apart, while 8 to 16 feet is typical for more confined lots.
        3) A tape measure may be used to measure out the exact spot for each post, or the distance between them may simply be estimated by pacing out the distance.
    c) Mark the ground line on the posts; line posts are usually set 30 inches into the ground.
    d) Dig the holes to the proper depth and set the posts in packed dirt.
    e) A level may be used to check the posts' plumbness.
    f) An alternative method of placing wood posts is sharpening and driving them into the ground with a post maul or a hydraulic post driver mounted on a tractor.
    g) Special considerations for setting any line posts are topography and ground conditions.
        1) Wet areas will typically require a longer post driven deeper into the ground to provide stability for the fence.
        2) Posts set in low areas may need special bracing to keep them from lifting out of the ground.

5. Ask students to list the tools needed to install steel posts and braces.

What tools are needed for installing steel posts and braces?

a) Chain saw
b) Ax
c) Heavy equipment
d) Metal post driver
e) Set of wrenches or a socket set for bolts
f) Portable arc welder
g) Fencing pliers or special tool for fasteners
h) Portable cement mixer or a wheelbarrow
i) Shovel
j) Buckets or a hose to supply water for concrete

6. Discuss how to install steel post-and-brace assemblies at a corner or along a fence line. Use TM 2.3 to illustrate the installation of a corner post.

How are steel post-and-brace assemblies installed?

a) Dig the anchor post hole.
    1) Should be 3 feet deep
    2) Provides more stability if it is approximately 20 inches in diameter at the bottom and 18 inches in diameter at the top
b) Mark the ground line on the post.
c) Bolt or weld the braces to the anchor post.
d) Dig holes where the braces touch the ground.
    1) Must extend 6 inches below the frost line
    2) Should be a minimum of 18 inches deep and preferably deeper, usually 2 to 3 feet
e) Place the concrete around the post and braces.
f) Mold the top of the concrete to slope away from them.
g) Use a level to make sure the post is plumb.

7. Discuss the procedures for installing a steel line post.

How are steel line posts installed?

   a) Measure the line post spacing and align the posts.
   b) Mark the ground line on the posts, which are set 2 to 3 feet deep.
   c) Drive the posts to the proper depth using a steel post driver.

8. Collecting some pictures of gates and displaying them will help stimulate interest in this topic. Discuss the following factors with the class.

   What are the factors to consider when installing a gate?

   a) A heavy gate will provide a counter force to the pull of the fence, so the weight of the gate should be taken into account when tensioning the brace structure.
   b) Gates should not be hung from lone posts.
   c) A larger post, 7 inches in diameter or more, should be used for the gate post.
   d) Gates should be hung in line with the fence structure, providing maximum support.
   e) If double gates are hung, a brace assembly must be installed on both sides of the opening.

F. *Other Activities*

1. Examine fences around the school or community to investigate methods of bracing.

2. Ask a local fencing contractor to speak to the class about new types of fencing and fence bracing.

G. *Conclusion*

Installing wood or steel posts is the first step in building a fence. Careful installation of both anchor-and-brace assemblies and line posts is necessary to construct a sturdy fence. Gates should also be installed with care, because their size and weight can have an effect on the fence.

H. *Answers to Activity Sheet*

1. They add strength to the fence, ke wires tight, and allow line wires to be tightened.

2. The fence would have little overall strength, and all wires would become very loose.

3. The twist wire pulls the posts toward each other.

I. *Answers to Evaluation*

1. d
2. c
3. c
4. b
5. d
6. a
7. Twist stick

8. Answers may include any two of the following: type of fence, topography of the ground, type of ground, length of the fence run, and bends in the fence line.

9. They must be driven deeper into the ground.

10. Answers may include any two of the following: a set of wrenches or a socket set for bolts, a portable arc welder, and fencing pliers or a special tool for fasteners.

UNIT VII - FENCING

Name ____________________________

Lesson 2: Setting and Bracing Posts

Date ____________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. The recommended size for wood line posts is:

   a. 2 inches in diameter.
   b. 3½ inches in diameter.
   c. 4½ inches in diameter.
   d. 5 inches in diameter.

2. How deep are steel line posts generally set?

   a. 1 to 2 feet deep
   b. 1½ to 2½ feet deep
   c. 2 to 3 feet deep
   d. 2½ to 3½ feet deep

3. How deep are wood line posts usually set?

   a. At least 10 inches
   b. At least 20 inches
   c. At least 30 inches
   d. At least 40 inches

4. What is the first step in installing steel post-and-brace assemblies?

   a. Mark the ground line on the post.
   b. Dig the anchor post hole.
   c. Bolt the braces to the post.
   d. Dig holes for the braces.

5. How large should a gate post be?

   a. At least 4 inches in diameter
   b. At least 5 inches in diameter
   c. At least 6 inches in diameter
   d. At least 7 inches in diameter

6. What type of wire is preferred for wire braces?

   a. 12½ gauge high tensile smooth wire
   b. 12 gauge barbed wire
   c. 10½ gauge smooth wire
   d. 10 gauge high tensile smooth wire

Complete the following short answer questions.

7. What is used to tighten a brace wire?

8. What are two factors that may affect the placement of an anchor-and-brace assembly along a fence line?

a.

b.

9. What must be done to provide more stability for line posts set in wet areas?

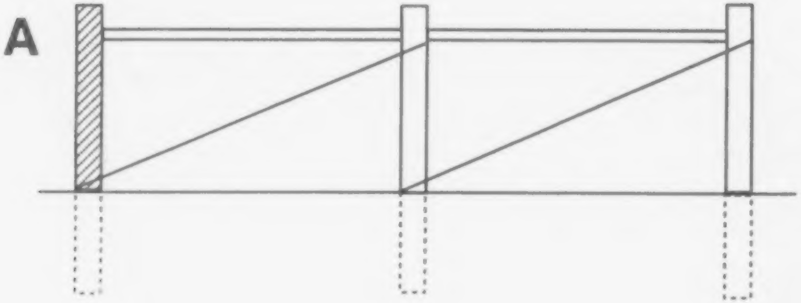
10. What are two tools used to attach braces to steel posts?

a.

b.

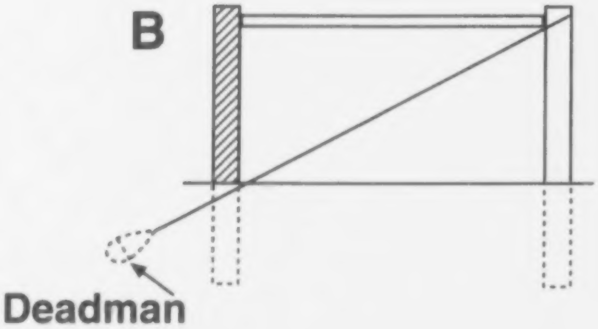
Anchor-and-Brace Assemblies

A

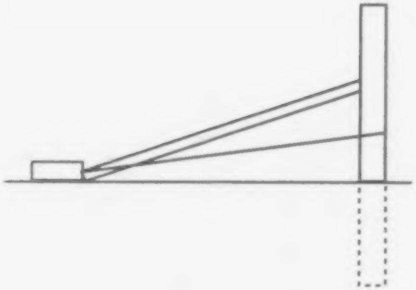


Double H

B

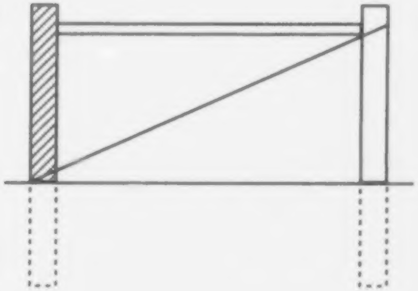


C



Angle Brace

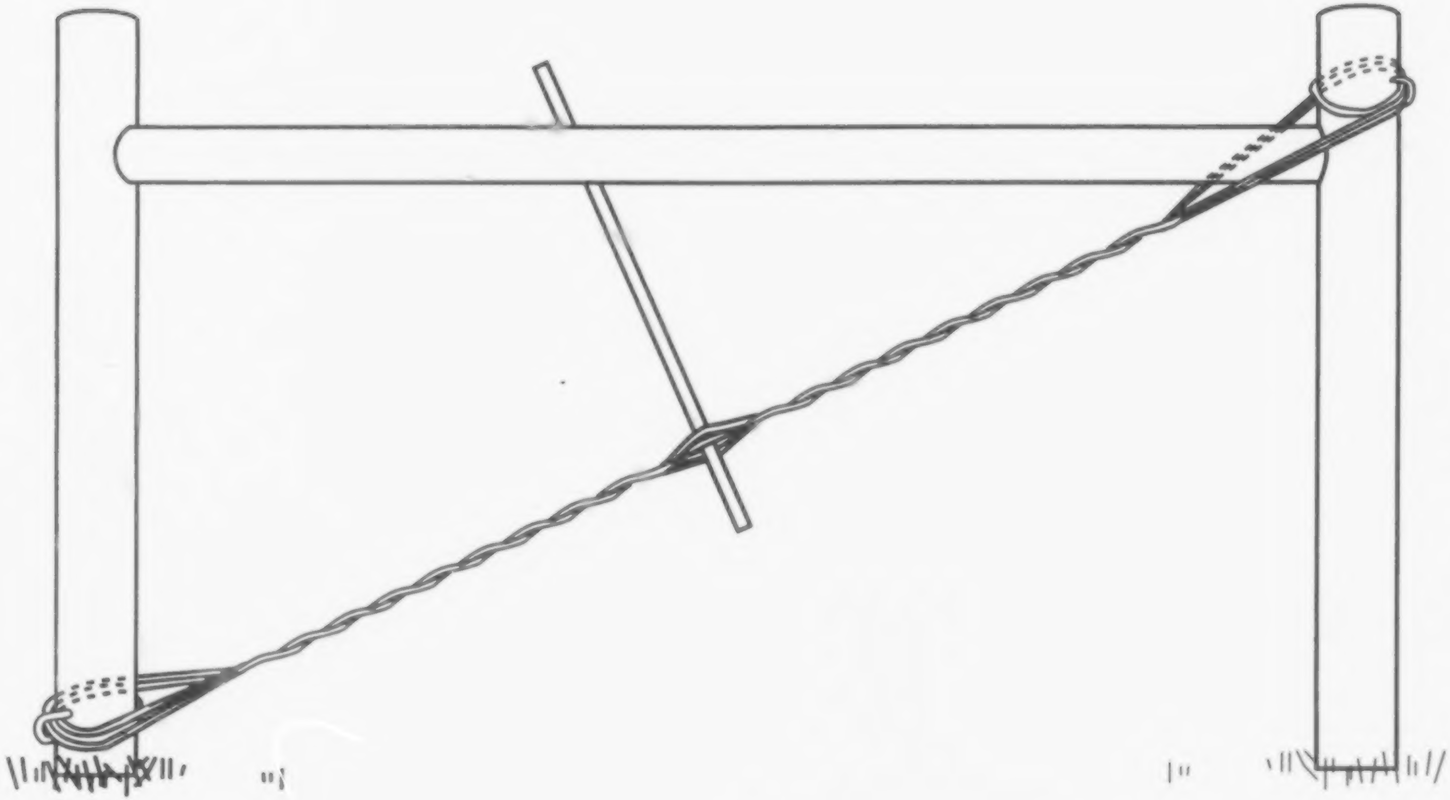
D



H-Brace

Agricultural Structures, VII-19

H-Brace

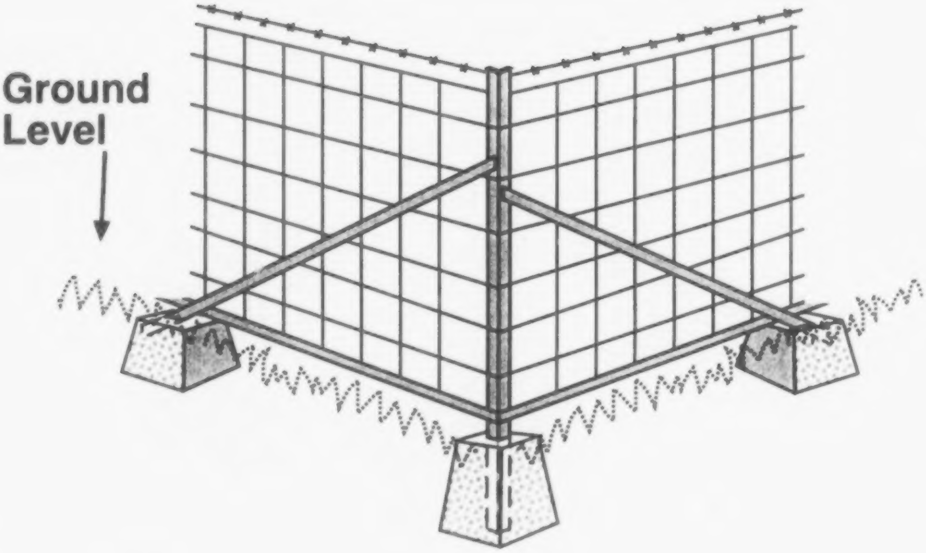


Agricultural Structures, VII-21

TM 2.2

TM 2.3

Metal Corner Post and Braces


Ground
Level

Lesson 2: Setting and Bracing Posts Name ______________________

Constructing Model Brace Assemblies

Objective: Construct model brace assemblies similar to those used in fencing.

Materials and Equipment:

1 8-foot 2" × 4"
1 4-foot ½" dowel
Hacksaw
½-inch drill bit
Drill
Wood glue
Wood chisel
1 12d nail
2 feet of thin wire (.035 MIG wire)

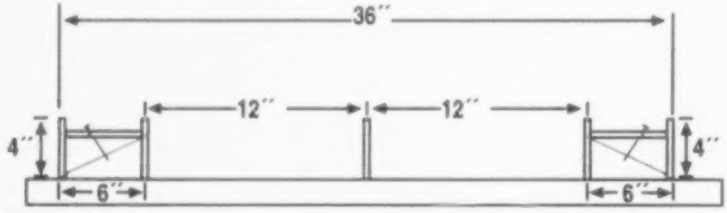


Figure 1.1

Procedure:

In this activity, you will construct a model (Figure 1.1) of a wood post fence that is 36 feet long, including the corner bracing. The model will be on the scale of 1" = 1'.

1. On your 2" × 4", mark on the board where the end posts will be placed. Drill holes 1 inch in depth into the board for the dowel posts.
2. At each end of the fence, brace posts will be placed 6 inches from the end post. Mark their location on the board and drill these holes.
3. The line posts in the middle will be 12 inches from the brace posts, with 12 inches between them. Mark their location and drill the holes.
4. Cut the dowel in 6-inch lengths to make six fence posts
5. Before inserting any dowels into the holes, notch the brace posts for the brace pole. The top of the brace will be placed 4 inches above the surface. Mark the position on four of the posts, and cut a notch into the post that is ½ inch in diameter and only about ¼ inch into the post. Using the wood chisel, chip out the material between the cuts where the brace will be inserted.
6. Place a small amount of glue in the brace assembly holes at each end of the fence. Insert the four posts in the base so that the notches in the end and brace posts face each other.
7. Once these posts are in place, measure and cut the braces to the correct length.
8. Using wood glue, insert the brace in the notches of the brace assembly at one end of the model.
9. Wrap the wire around the posts forming the brace assembly. The wire should wrap around the bottom of the end post and the top of the other post.
10. Pull the wire as tight as possible. Tie the ends together tightly.
11. Insert a nail between the two wires in the middle of the brace span and begin twisting. Twist until the wire is tight and begins to cut into the dowel.

12. When the wire is tight, let the nail rest against the brace.

13. Wrap more wire around the nail and brace to hold the nail in place.

14. Repeat steps 8-13 for the brace assembly at the other end of the board.

15. Using a small amount of glue, insert the other two posts.

16. Optional - Using more of the wire, finish the model as if it were a 4-wire barbed wire fence. Fasten your wire to the posts using a hand staple gun.

Key Questions:

1. Why are fences braced in this manner?

2. How would the strength of the fence be affected if the brace assemblies broke?

3. What does the twist wire do?

UNIT VII - FENCING

Lesson 3: Barbed and Woven Wire Fences

Competency/Objective: Describe techniques for building barbed and woven wire fences.

Study Questions

1. **What materials and tools are needed to install barbed wire fencing?**
2. **How is barbed wire laid out on the fence line?**
3. **How is barbed wire stretched?**
4. **How is barbed wire attached?**
5. **What materials and tools are needed for woven wire?**
6. **How is woven wire laid out?**
7. **How is woven wire stretched?**
8. **How is woven wire attached?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit VII.
2. Transparency Masters
    a) TM 3.1: Staple Positioning
3. Activity Sheet
    a) JS 3.1: Constructing Barbed Wire Fencing

UNIT VII - FENCING

Lesson 3: Barbed and Woven Wire Fences

TEACHING PROCEDURES

A. ***Review***

Lesson 2 described how wood and steel posts should be set when building fences for agricultural operations. Barbed and woven wire fences are two common types of fences in agriculture. In this lesson, the materials, tools, and wire installation techniques for these types of fences are outlined.

B. ***Motivation***

Display some basic fencing materials and tools, such as staples, fencing pliers, and fence stretchers. Ask students to explain how they are used for fencing.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Some samples of barbed wire (consisting of a few inches of 12½ and 14 gauge wire with 2 or 4 points) will be of help in presenting this lesson. Discuss the following materials and tools with the class.

What materials and tools are needed to install barbed wire fencing?

a) Materials
    1) Barbed wire - fencing material made of wire strands twisted together with wire barbs placed at various intervals
        (a) Gauge
            (1) Number representing the diameter of the wire, with a lower number corresponding to a larger diameter
            (2) 12½ and 14 gauge - most common in Missouri
        (b) Number of barbs - most commonly two and four points
        (c) Wire coating
            (1) Zinc
            (2) Aluminum
        (d) Made of soft wire or high tensile wire
    2) Staples or metal clips
b) Tools
    1) Claw hammer
    2) Fencing pliers
    3) Fence stretcher

2. Discuss how a barbed wire fence is laid out.

How is barbed wire laid out on the fence line?

a) Wrap the bottom strand of the wire around a corner post two or three times and staple it securely.
b) Twist the end of the wire tightly around the wire strand.
c) The number of strands of wire used determines the height of the bottom strand.
d) Unroll the wire along the fence line on the stock side of the posts.

        1) The length unrolled depends on the topography, fence layout, and the position of fence brace structures.
        2) Barbed wire comes in rolls of wire a quarter mile long; the entire length of the wire can be laid out at once under the proper conditions.
        3) Using short stretches of wire is more costly.
    e) Use the same procedure for each strand, from the bottom to the top.
    f) Place the wire as close as possible to the fence line.
    g) Walking the fence line and moving the wire into place may be necessary to help remove excess slack prior to stretching the wire.

3. Show students a wire stretcher. If possible, demonstrate how hand-operated fence stretchers work. Discuss how wire is stretched.

How is barbed wire stretched?

- a) Attach the stretcher to the wire being stretched.
    - 1) The stretcher can be attached to a solid object in line with the wire, usually the post of a brace structure or a piece of equipment.
    - 2) For longer stretches, the wire can be stretched and spliced in the middle to distribute the pull more evenly; the stretcher then connects to the wire only.
- b) The length of wire to be stretched at a time depends on the topography of the area and the stretching tools.
    - 1) Hilly areas require stretching short sections at a time to keep the wire level.
    - 2) A rule of thumb is to stretch from 5 to 20 rods at a time.
    - 3) Stretching longer sections of wire will take less time.
- c) Slowly stretch the wire just to the point of being relatively tight and straight.
- d) Depending on the length of the stretch, it may be necessary to walk along the fence line and untangle the wire.

4. Show the class some examples of fence staples and metal post clips and discuss how they are used to attach barbed wire. Use TM 3.1 to illustrate how staples should be set in a wood post. If possible, demonstrate how wire clips work with a steel post. Hand out JS 3.1. In order for students to practice constructing a barbed wire fence, solid posts should already be in place to complete this activity.

How is barbed wire attached?

- a) Attach the wire to the post while the stretchers are still in place.
- b) The end of the wire should be long enough to wrap completely around the post twice and then be tied off back onto the wire.
- c) Staple the wire to the post.
- d) Use staples to attach wire to wood posts.
    - 1) Set the staples at a slight downward angle diagonal to the side of the post.
    - 2) Drive the staple into the post.
    - 3) Staples should not be driven in so tightly that they and the wire become embedded in the post.
- e) If steel posts are used, attach the wire using metal clips.

5. Show the class pictures of different types of woven wire. Discuss the tools needed to install it.

What materials and tools are needed for woven wire?

- a) Materials
    - 1) Woven wire
        - (a) Fencing material in which wires are connected together to form a mesh
            - (1) Hinge lock - has short pieces of wire wrapped into a knot at each horizontal wire, so the stay is not one piece of wire

            (2) Stiff stay - has a continuous stay with short sections of wire forming the knots that attach the stay to the horizontal wire
        (b) Either soft wire or high tensile wire
        (c) System of labeling - a three-number designation identifying the number of horizontal wires, the height of the fence, and the distance between vertical stay wires

b) Tools
    1) Claw hammer
    2) Fencing pliers
    3) Fence stretcher

6. Discuss how woven wire is laid out along the fence line.

How is woven wire laid out?

a) Unroll the wire past the corner post on the side of the post to which the wire will be attached.
b) Lay out enough wire to wrap around the post once.
c) Remove three or four stays to wrap around the post cleanly.
    1) Hinge lock fencing
        (a) Cut the stay in the middle of each block.
        (b) While using pliers to hold the knot, grab and twist the ends of the cut wire in the opposite direction from the knot.
        (c) The sections of the stay wire should slide off the horizontal wire.
    2) Stiff stay wire - Cut the small knot wire that holds the vertical stay in place.
d) Set the wire to the desired height against the anchor post.
e) Wrap the wires around the post.
f) Tie them off by splicing the end of each wire onto itself.
g) Roll out the wire either to the brace structure that it is to be attached to or to the point where it will be spliced onto another roll.
    1) Rolls of woven wire are 330 feet long.
    2) The maximum length that can be stretched at one time is a quarter mile, or four rolls of wire.
    3) For short stretches of wire, the wire will be rolled out past the brace structure to be stretched.
    4) If two or more rolls are required, one roll is fastened to a post at each end, and then the wire rolls are stretched and spliced in the middle.
    5) An alternative method is to attach one end of the first roll to a post and then tie the other end to the next roll to tighten the entire length at the same time; the wire will not be as tight.

7. Explain how woven wire is stretched.

How is woven wire stretched?

a) Woven wire can be stretched using stretcher boards.
    1) Wood stretcher boards are made of 2" × 4" boards that are bolted together to hold the woven wire.
    2) Metal stretcher boards can be purchased from retailers that carry fencing supplies.
b) Attach the stretcher boards to the wire a few feet past the post to which the wire will be tied off.
c) Attach the stretcher board in line with one vertical stay.
d) Wrap the ends of a heavy chain around the top and bottom of the boards.
e) Attach the cable winch-puller to the chain and to a secure point, such as a truck, tractor, or another anchor post.
f) Tension the fence slowly.
    1) Remove ½ to ⅔ of the tension bump.

        2) The wire is too tight if the tension bump is completely straightened.
    g) The fence may need to be shaken to free it from snags.

8. Discuss how staples and metal clips are used.

How is woven wire attached?

- a) Tie off each wire, one at a time.
    - 1) Cut the wire at a point far enough past the post for the wire to wrap the post.
    - 2) Any stays that might interfere with the post should be removed.
    - 3) Wrap the wire around the post, tie it off, and staple it tightly to the post.
- b) Remove the stretcher boards.
- c) Attach the horizontal wires to the line posts.
    - 1) With wood posts, staple each wire tightly.
        - (a) Set the staple and wire into the post.
        - (b) Place the staples crosswise with a slight downward angle.
    - 2) If metal posts are used, fasten wire clips according to the manufacturer's recommendations.
    - 3) For fences up to 4 feet tall, only five staples or clips are needed per post.
    - 4) Taller fences may require a few more fasteners.
    - 5) Attach the top and bottom wires at every post.
    - 6) Stagger the other fasteners on different wires at each post.

F. *Other Activities*

Observe a local fencing contractor constructing new fencing using barbed and woven wire. Have students observe techniques for stretching and attaching wires.

G. *Conclusion*

Fencing is essential for many agricultural operations. Barbed wire and woven wire fences are two common fence types. Similar materials and tools are needed to build these types of fences: barbed or woven wire, fasteners, a claw hammer, fencing pliers, and fence stretcher. In each case, the wire is laid out along the fence line, stretched properly, and then attached to the posts.

H. *Answers to Activity Sheet*

1. Tightening the wire could pull the post over.

2. The bumps on the post hold the wires in place.

3. The number of wires used will depend on the type of livestock for which the fence will be used.

I. *Answers to Evaluation*

1. a
2. d
3. b
4. d
5. a
6. At a slight downward angle diagonal to the side of the post
7. Hinge lock and straight stay
8. Claw hammer, fencing pliers, and fence stretchers
9. Stretcher boards
10. Top and bottom wires

UNIT VII - FENCING

Lesson 3: Barbed and Woven Wire Fences

Name ____________________________

Date ____________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. When installing barbed wire, which strand is attached first?

   a. Bottom
   b. Middle
   c. Top
   d. Any

2. Barbed wire can be attached to steel post with:

   a. Staples.
   b. Metal tape.
   c. Wire.
   d. Clips.

3. How many points does barbed wire commonly have?

   a. One or three points
   b. Two or four points
   c. Three or five points
   d. Four or six points

4. What is the rule of thumb for the length of wire to be stretched at one time?

   a. 2 to 5 rods
   b. 3 to 10 rods
   c. 4 to 15 rods
   d. 5 to 20 rods

5. When laying out woven wire, unroll enough to wrap the wires ______ around the post.

   a. Once
   b. Twice
   c. Three times
   d. Four times

Complete the following short answer questions.

6. How should staples be set in a wood post?

7. What are two types of woven wire?

   a.

   b.

8. What are three tools needed to install woven wire fences?

   a.

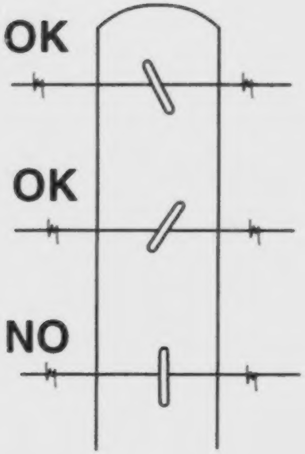
   b.

   c.

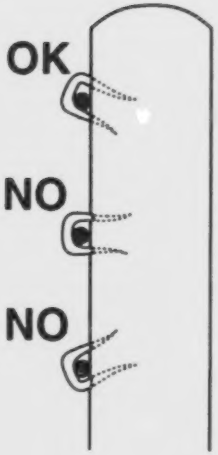
9. What special tool is used to stretch woven wire?

10. When attaching woven wire to posts, which wires should be attached at every post?

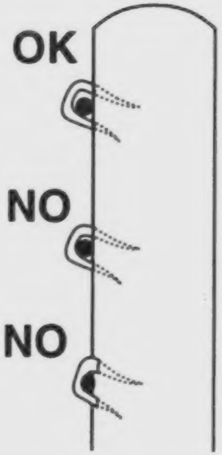
Staple Positioning



Staples at an Angle to Post's Side



Staples at Proper Angle



Wire Loose in Staple

Agricultural Structures, VII-35

Lesson 3: Barbed and Woven Wire Fence Name ____________________________

Constructing Barbed Wire Fencing

Objective: Practice the skills used in constructing barbed wire fencing.

Materials and Equipment:

Barbed wire
Fence stretchers
Metal fence posts
Metal post driver
Wire clips
Fencing pliers
Standard screwdriver
Claw hammer
Fencing staples

Procedure:

In this activity, you will be constructing a small sample barbed wire fence by stretching and applying the wire to posts to wood and metal posts.

1. Using the wood posts identified by your instructor as the end posts, lay out the steel posts where they will be driven into the ground. Steel posts should be placed about 15 feet apart.

2. Stand one of the posts upright in line with the two brace posts. Have another person help you align the post by looking to see whether line posts line up with the two end posts.

3. Turn the post so the ridges on the side of the post are at a 90-degree angle to the line of the post. The ridges help to keep the wire in line vertically on the post. It is important to make sure all the line posts are turned the same way.

4. Using the post driver, pound the post in until the metal clip towards the bottom of the post is completely underground, a distance of about 18 inches.

5. Repeat steps 2 through 4 until all the line posts are set.

6. Starting at one brace post, unroll enough wire to wrap around the post at least twice with another 2 feet to spare on the end.

7. Wrap the wire twice around the post 8 inches above the ground. Wrap the tail of the wire around the fence line wire at least three or four times.

8. Staple the wire to the wood post, pounding the staple in tightly enough to prevent slippage.

9. Unroll enough wire to reach the other brace post, cutting the wire so that there is enough to wrap around the post at least twice and an additional 2 feet.

10. Pull the wire as tight as possible by hand. Attach the fence stretchers to the wire.

11. Tighten the wire using the stretchers.

12. Repeat steps 7 and 8 at the other end post.

13. Attach the wire to the line posts at the desired height using wire clips.

14. For each additional wire, repeat steps 7 to 13. The top wire should be about 4 feet above the ground, and the two middle wires should be evenly spaced between the top and bottom wires.

UNIT VII - BUILDING FENCES

Lesson 4: High Tensile and Electric Fences

Competency/Objective: Describe techniques for building high tensile and electric fences.

Study Questions

1. **What are the advantages of high tensile fencing?**
2. **What are the components of high tensile fencing?**
3. **How are high tensile fences constructed?**
4. **What are the advantages of electric fences?**
5. **What are the components of electric fences?**
6. **How should electric fence chargers be selected?**
7. **How are electric fences constructed?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit VII.
2. Transparency Master
    a) TM 4.1: Electric Fencing Components
3. Activity Sheet
    a) AS 4.1: Tensioning Fences

UNIT VII - BUILDING FENCES

Lesson 4: High Tensile and Electric Fences

TEACHING PROCEDURES

A. ***Review***

Lesson 3 discussed barbed and woven wire fencing, which are commonly used for agricultural purposes. Other types of fences frequently used in agriculture are high tensile and electric. This lesson outlines some basics for both types of fencing.

B. ***Motivation***

Ask the students if they have come in contact with an electric fence. Have them describe the sensation they experienced. Describe how the shock is transmitted from the fence to people or livestock that come into contact with it.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Ask the students to list some advantages of high tensile fencing. Discuss the properties of high tensile wire.

What are the advantages of high tensile fencing?

a) Chief advantage - high tensile strength, which allows the wire to take a large amount of stress before breaking
b) Longer life span
c) Lower maintenance requirements
d) Versatile, coming in a variety of forms
e) Easier to handle than barbed or woven wire
f) Easily electrified
g) Good choice to replace barbed wire when the animals being fenced need protection from the barbs, as in the case of show animals

2. Describe the components of high tensile fences and discuss them with the class.

What are the components of high tensile fencing?

a) High tensile wire
b) Wood or steel posts
    1) Either rounded or square wood posts
    2) Wood corner posts at least 5 inches in diameter
    3) Brace posts at least 4 inches in diameter
    4) Line posts at least 3½ inches in diameter
c) Fasteners
    1) Staples that are 1¾ to 2 inches long
    2) Wire clips
d) Spacers called battens, stays, or droppers
    1) Replace some of the line posts in holding the wire in place
    2) Made of wood, steel, or fiberglass
e) Permanent in-line strainers or tension springs

3. Ask students to review the steps in constructing barbed and woven wire fences. Discuss their similarity to the steps in high tensile fence construction.

How are high tensile fences constructed?

a) Set the anchor post and brace structure; double brace structures should be used because they can hold more tension.
b) Set the line posts, spacers, and line brace structures.
    1) Include line brace structures at appropriate intervals and at the top and bottom of slopes.
    2) Set the line posts 2½ feet into the ground for stability.
    3) The distance between line posts will vary with the purpose of the fence; 16 feet apart is a good rule of thumb for large pastures with little pressure on the fence.
    4) The use of spacers allows them to be set further apart.
c) Attach the wires working from the bottom to the top.
d) Place a spinning jenny somewhere in the middle of the span.
e) Pull the first wire from the spinner to one brace structure.
f) Wrap it around the post twice and tie it off.
g) Cut the wire at the spinner.
h) Attach the strainer to the end of the wire.
i) Pull the wire from the spinner to the other brace structure and tie it off.
j) At the spinner, run about 3 feet of wire past the strainer and cut the wire.
k) Place the end of this wire in the strainer, and take up tension by turning its drum.
l) After applying some tension, loosely staple the wire in place.
m) Once all the wires are in place, tighten the wires to the proper tension and staple them to the posts, with the wire left slightly loose in the staples.
n) Attach the wires to the spacers.

4. Have students list all the advantages they can think of concerning electric fences. Could they be considered low maintenance? Why or why not?

What are the advantages of electric fences?

a) Low in cost
b) Quick and easy to construct
c) Versatile - used for all types of animals
d) Long life span because the animals generally leave the fence alone
e) No physical damage to animals from shock

5. Ask students to list the components of an electric fence. If possible, show the class a charger, ground rod, and sample insulators. Show students TM 4.1.

What are the components of electric fences?

a) Wire
    1) 12½-gauge or 14-gauge high tensile or soft wire
    2) Poly-wire
        (a) Useful alternative for temporary fences
        (b) Stranded polyethylene wire that has smaller wire conductors embedded in it
b) Fence charger
c) Ground rod
d) Posts
    1) Wood posts that are at least 5 or 6 inches in diameter
    2) Steel posts
    3) Small fiberglass rods 3 to 5 feet in length for constructing a temporary fence
e) Insulators

6. Discuss considerations that affect the selection of a fence charger.

How should electric fence chargers be selected?

a) Location of the fence
  1) Determines if electricity is available
  2) Battery types
    (a) Useful for remote areas
    (b) Solar-powered battery charger built into the charger in some units
  3) Plug-in chargers - used to take advantage of main line power where electricity is available
b) Voltage put out by the charger
c) Length of the fence
d) Amount of vegetation
  1) Grass and weeds - rob the fence of some of its power
  2) Low impedence fence chargers
    (a) Useful when vegetation is high
    (b) Increases its energy output as power is drained off by plants touching the fence
e) Species of livestock
  1) Less voltage needed for animals that have thin coats
    (a) Horses
    (b) Short-haired cattle
  2) Higher voltages required for animals with thicker coats
    (a) Sheep
    (b) Goats
f) Safety - approved by the Underwriters Laboratories or another reputable agency

7. Describe the process for constructing an electric fence.

How are electric fences constructed?

a) Install the charger in a dry, protected area.
b) Set the ground rod in place and attach it to the charger.
  1) The ground rod must be in solid contact with moist earth, which may mean driving it to a depth of up to 6 feet.
  2) Drier conditions may require the use of more than one rod.
c) Clamp a heavy wire to the top of the rod and attach the other end to the charger's ground terminal.
d) When the posts and wire for the fence are in place, run another wire from the positive terminal of the charger to the electric fence or to a lead wire.
e) If permanent posts are in place, they should be used; if not, set the posts in place.
  1) The posts should be set to a depth of 3 to 3½ feet.
  2) The distance between the posts may vary between 20 and 50 feet.
  3) For a temporary fence, the corner and line posts are set to a depth that feels solid.
f) Place the insulators on the posts at two-thirds of the height of the livestock being fenced.
g) Attach the wire to the posts.
  1) One or two strands of wire are sufficient for an electric fence.
  2) Attach the end of the wire to the insulator on the anchor post, and unroll the wire along the fence line.
  3) Stretch soft wire using fence stretchers.
  4) Attach it to the insulators.
  5) If high tensile fencing is used, the wire should be laid out and stretched as appropriate.

F. ***Other Activities***

1. Have the students collect some electric fence insulators to use as examples when teaching this lesson.

2. Allow students to observe a local fencing contractor building a high tensile fence.

G. ***Conclusion***

High tensile and electric fencing have many advantages for agricultural operations. High tensile wire is useful where strong wire that does not break easily is needed. Among the advantages of electric fencing are low cost and ease of construction. High tensile fencing is often electrified to provide the advantages of both types of fencing.

H. ***Answers to Activity Sheet***

1. To tension or tighten the wire

2. Wires should not be stretched tightly on hot days because the wire will contract as it cools and possibly break. Wires should not be left loose on cold days, as the wire will expand as temperatures increase, leaving too much slack in the wire.

3. Putting the strainer in the middle will provide more even tension through the span.

I. ***Answers to Evaluation***

1. d
2. c
3. b
4. d
5. Two-thirds of the height of the livestock being fenced
6. The location of the fence, the voltage put out by the charger, and safety
7. Because they can hold more tension

8. Answers may include any two of the following: low cost, quicker and easier construction, versatile, long life span, and no physical damage to animals from shock.

9. To maintain the tension on the wire

10. A component of high tensile fences that can replace some of the line posts holding the wire.

UNIT VII - BUILDING FENCES

Name ______________________________

Lesson 4: High Tensile and Electric Fences

Date ______________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is a component of an electric fence?

   a. Spacers
   b. Stays
   c. Staples
   d. Ground rod

2. What is the main advantage of high tensile fencing?

   a. It is low in cost to construct.
   b. It does not need to be electrified.
   c. It can take a large amount of stress.
   d. It requires only small rods for posts.

3. In pastures with little pressure on the fence, how far apart can the posts of a high tensile fence be spaced?

   a. 14 feet
   b. 16 feet
   c. 18 feet
   d. 20 feet

4. How far apart are the posts in an electric fence generally set?

   a. 5 to 15 feet
   b. 10 to 30 feet
   c. 15 to 45 feet
   d. 20 to 50 feet

Complete the following short answer questions.

5. At what height should insulators be placed on a fence post?

6. What are three factors to consider when choosing a charger for an electric fence?

   a.

   b.

   c.

7. Why are double brace assemblies useful with high tensile fencing?

8. What are two advantages of electric fences?

   a.

   b.

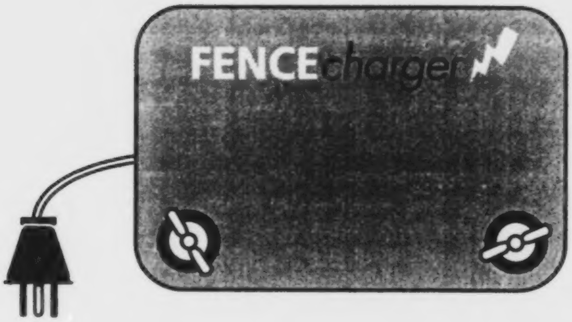
9. What is the purpose of adding a permanent in-line strainer when building a high tensile fence?

10. What are stays?

TM 4.1

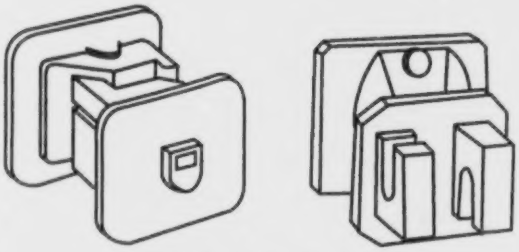
Components of Electric Fences

Fence Charger

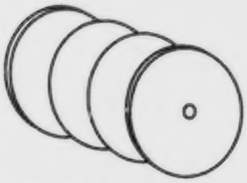


Insulators

Wood Post Insulators

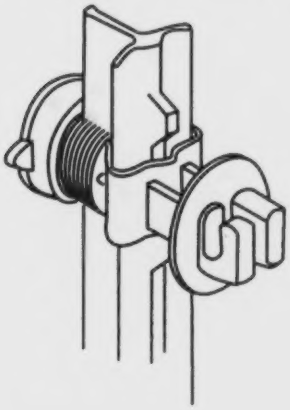


Square Insulator



Nob Insulator

T-Post Insulator



Lesson 4: High Tensile and Electric Fences Name ____________________

Tensioning Fences

Objective: Tension an electric fence.

Materials and Equipment:

14-gauge soft wire
Strainer
Wire cutters

Procedure:

In this activity, you will practice tensioning soft wire using the process described for high tensile wire in your student reference.

1. Wrap the wire at least twice around a post selected by your instructor. Wrap the tail of the wire around the fence line wire at least three or four times.
2. Unroll enough wire to span approximately half the length of the fence, and cut the wire.
3. At the opposite post, repeat step 2.
4. From the second post, unroll enough wire to reach the first wire and extend 2 to 3 feet beyond it.
5. Run one wire through the hole on the body of the strainer and tie or crimp the wire to the strainer.
6. Run the other wire into the hole on the drum of the strainer.
7. Turn the drum until the wire is relatively tight.

Key Questions:

1. What is the purpose of the strainer?

2. Suppose that you are going to tighten the wire in more extreme weather conditions, when it is 35 or 90 degrees Fahrenheit. How would these temperature extremes affect how much you would tighten the wire?

3. Why is putting the strainer close to the middle of the span recommended?

UNIT VII - FENCING

Lesson 5: Fence Mending Techniques

***Competency/Objective*:** Identify fence mending techniques.

Study Questions

1. **What are the methods of tightening fence wires?**
2. **What are the tools available for mending broken wires?**
3. **What are the different methods of splicing?**
4. **How are posts replaced in an existing fence line?**

References

1. *Agricultural Structures (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1999, Unit VII.
2. Transparency Master
    a) TM 5.1: Using a Compression Sleeve
    b) TM 5.2: Splicing Woven Wire
3. Activity Sheet
    a) AS 5.1: Splicing Wire

Lesson 5: Fence Mending Techniques

TEACHING PROCEDURES

A. ***Review***

Lesson 4 described the advantages of high tensile and electric fencing and how these types of fences are built. All fences require maintenance and repair, because use and age causes fences to deteriorate and break. Repairs are generally simple and are effective in extending the life of the fence. This lesson, Lesson 5, outlines the practices for keeping a fence in good order.

B. ***Motivation***

Discuss some of the problems that occur that make fence repairs necessary. Examples are breaks in a wire or post, vegetation growing into the wire, rot or fire damage to wood posts, fasteners coming loose, etc.

C. ***Assignment***

D. ***Supervised Study***

E. ***Discussion***

1. Discuss procedures for tightening wire with students. Refer back to Lessons 3 and 4 for information on stretching different types of wire.

   What are the methods of tightening fence wires?

   a) Stretching the wire at a post
      1) Detach the wire from an anchor post and loosen it at the line posts.
      2) Stretch the wire at the anchor post.
      3) Reattach the wire to the posts.
   b) Stretching the wire in the middle of the fence line
      1) Cut the wire in the middle of the fence.
      2) Attach the fence stretchers at this point.
      3) Stretch the wire.
      4) Splice the ends of the wire together.

2. Display the tools used to mend wires while discussing them with students. Mention that fencing pliers can perform the task of hammering, splicing, and compressing sleeves, though usually not as efficiently as specialized tools.

   What are the tools available for mending broken wires?

   a) Claw hammer
   b) Fencing pliers
   c) Fence stretchers
   d) Splicing tools
      1) Sleeve compressor
      2) Woven wire splicing tool

3. Using some smooth wire, demonstrate how to splice wire to the class. TMs 5.1 and 5.2 can also be used to illustrate the use of a compression sleeve and a woven wire splicing tool. Have students complete AS 5.1.

What are the different methods of splicing?

- a) Barbed or smooth wire
  - 1) Preferred method - crimp splice using a metal compression sleeve
    - (a) Thread both ends of the wire through the sleeve.
    - (b) Press the sleeve together tightly using the fencing pliers.
  - 2) Wrap splice
    - (a) This type of repair seldom produces as tight a bond.
    - (b) Lacerations to the hands are more likely.
- b) Woven wire
  - 1) Twist the wires together tightly using a splicing tool or pliers.
  - 2) These splices may cause lacerations to the hands, so heavy gloves should be worn.

4. Discuss the process for replacing fence posts if the existing posts can no longer support the fence effectively.

How are posts replaced in an existing fence line?

- a) Detach the wire from the post and remove the post from the ground.
  - 1) Sometimes posts can be loosened by rocking them back and forth and then pulled out by hand.
  - 2) Posts may also be removed using post pullers or a jack.
  - 3) Sometimes a post breaks off at ground level.
    - (a) If possible, the new post is set to one side of the old post.
    - (b) If it is not possible, digging up the old post is necessary.
- b) Set the new post in place.

F. *Other Activities*

Using smooth wire, have students practice making splices with compression sleeves. They may also practice wrap splices.

G. *Conclusion*

For agricultural operations, fence repairs are frequently a necessity. Mending fences may require tightening wires, splicing broken wires, or installing new posts. These repairs are generally fairly simple and require relatively few tools.

H. *Answers to Activity Sheet*

1. Crimp splice

2. Crimp splice

3. Older wires generally will not splice well and could break.

I. *Answers to Evaluation*

1. d
2. b
3. c
4. A sleeve compressor and woven wire splicing tool
5. Post pullers or a jack

6. The wires are twisted together tightly using a splicing tool or pliers.

Name ____________________________

Date ____________________________

EVALUATION

Circle the letter that corresponds to the best answer.

1. What is the preferred method of splicing barbed or smooth wire?

   a. Using a smooth wire splicing tool
   b. Twisting the wire with fencing pliers
   c. Tying the wire by hand
   d. Using a compression sleeve

2. Which of these steps would be done first when tightening fence wires?

   a. Fasten the wire tightly to the posts.
   b. Detach the wire from the anchor post.
   c. Attach the fence stretchers at the post.
   d. Remove the fasteners along the length of the wire.

3. What should be done if a post breaks off at ground level?

   a. The broken post should be driven deeper into the ground.
   b. The broken post should be pulled out of the ground with a chain.
   c. The new post should be set to one side of the broken post.
   d. The new post should be set on top of the broken post.

Complete the following short answer questions.

4. What are two specialized tools for mending broken wires?

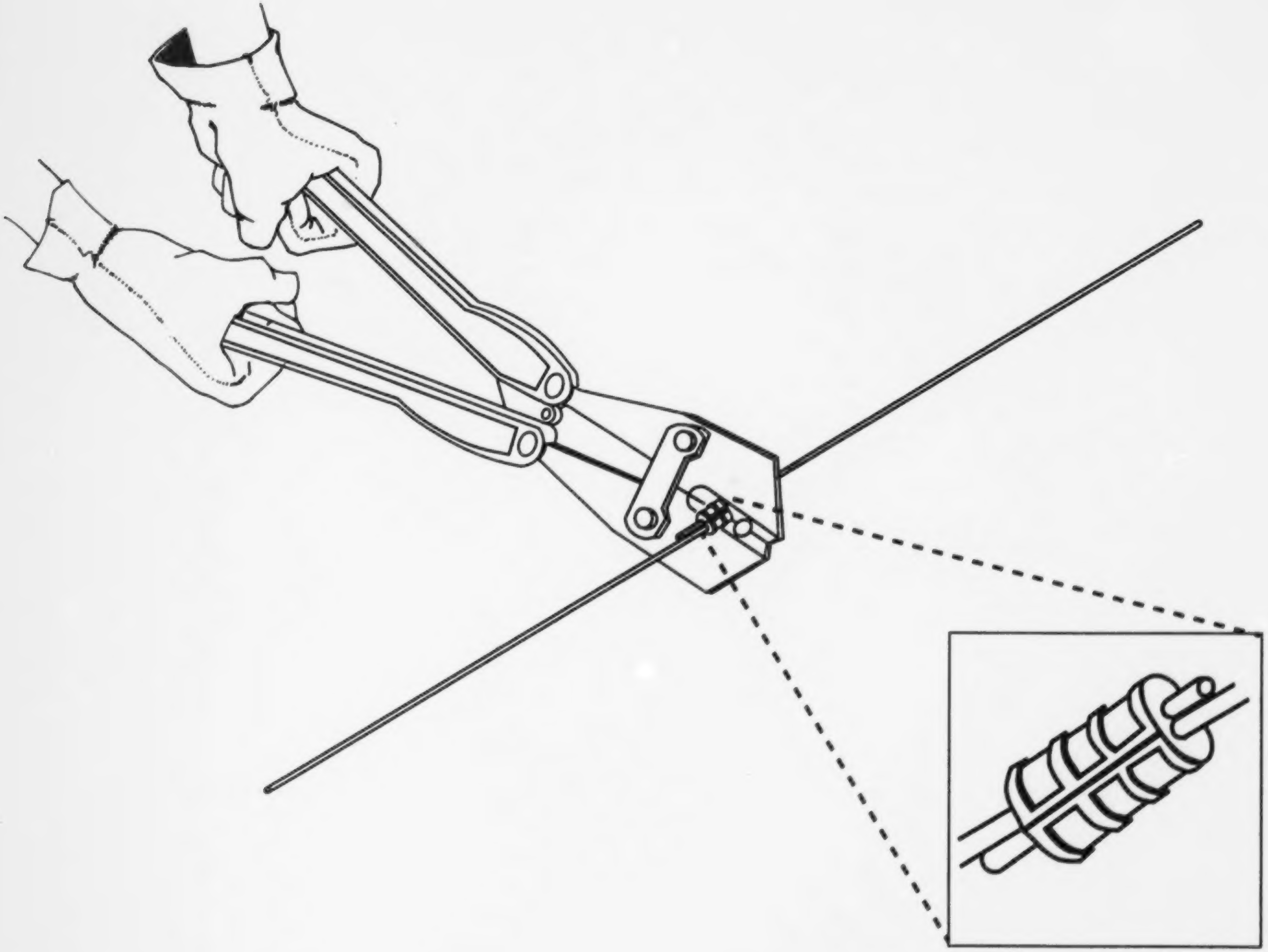
   a.

   b.

5. If a post is difficult to remove by hand, what can be used to move the post?

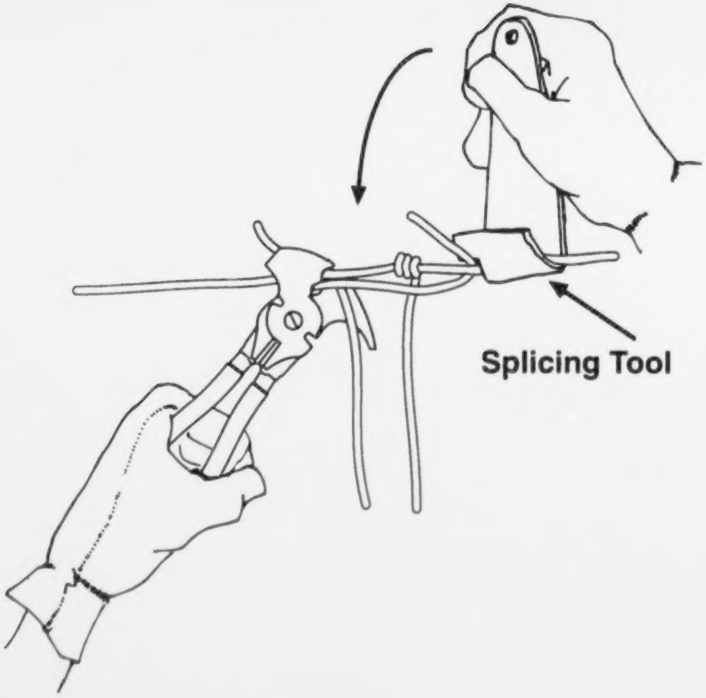
6. How are the wires of a woven wire fence spliced together?

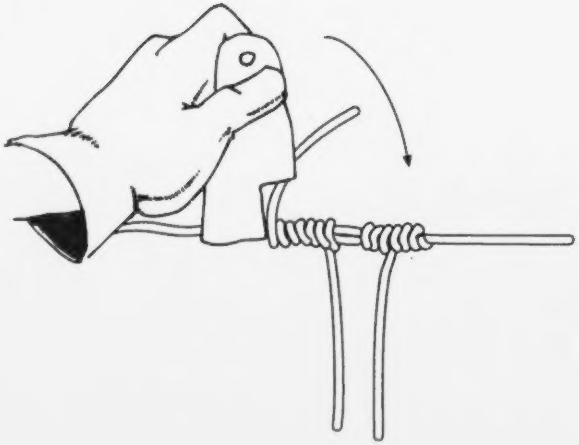
Using a Compression Sleeve



TM 5.1

Splicing Woven Wire


Splicing Tool



Agricultural Structures, VII-59

Lesson 5: Fence Mending Techniques

Name ______________________________

Splicing Wire

Objective: Practice wire splicing techniques.

Materials and Equipment:

14-gauge soft electric wire, cut into four 2-foot pieces
Compression sleeve
Sleeve compressor or fencing pliers

Procedure:

Crimp splice

1. Insert the ends of two sections of wire into the compression sleeve.
2. Crimp the sleeve down using the sleeve compressor or fencing pliers.

Wrap splice

1. On one of the other pieces of wire, form a 2-inch loop. Wrap the tail of the wire around the main wire three or four times.
2. Holding the looped wire in your left hand, run the other wire about 8 inches through the loop with your right hand.
3. Bend the wire in your right hand back over to the right. Wrap this wire around the wire in your right hand at least three or four times.

Key Questions:

1. Which splice would be quicker to apply?

2. Which splice uses tools?

3. What effect would the general condition of the wire (age, rust, etc) have on the second type of splice?

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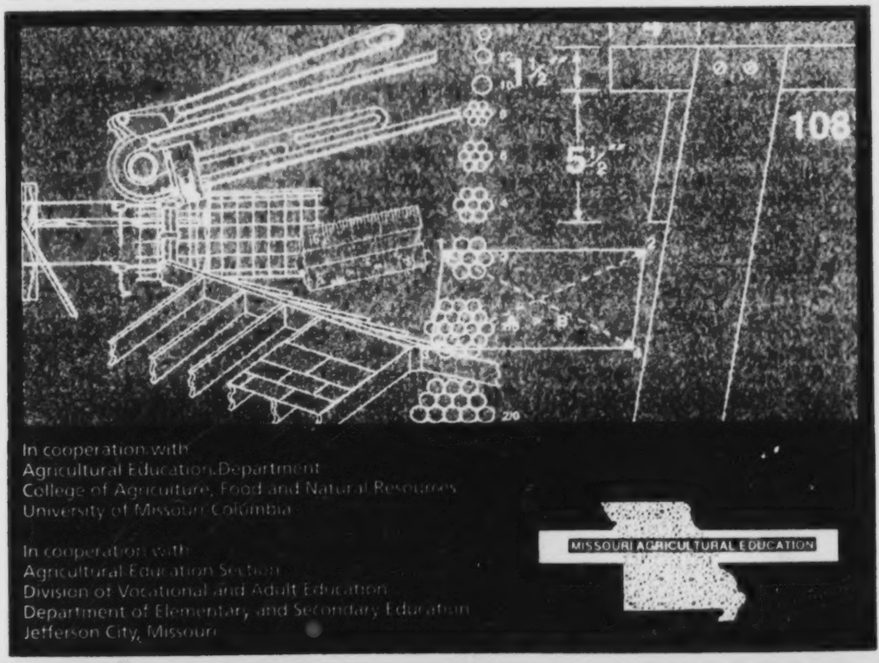
Agricultural Structures

STUDENT REFERENCE



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University of Missouri-Columbia

In cooperation with
Agricultural Education Section
Division of Vocational and Adult Education
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MISSOURI AGRICULTURAL EDUCATION

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FOREWORD

The development of the *Agricultural Structures* curriculum guide is the result of suggestions by the MVATA Teaching Aids Committee. The Agricultural Structures Advisory Committee suggested the topics to be included and reviewed the materials.

This curriculum contains seven units. Topics include working with plans, home and farmstead planning, building construction, concrete, electricity, plumbing, and fencing. An instructor guide can be purchased separately.

During the summer of 1981, the Missouri State Board of Education formally adopted the concept of "Instructional Management Systems" (IMS) as a priority for the 1981-82 school year. The Missouri Commissioner of Education described the IMS concept as a practical way of "organizing for excellence" in education. To meet the demand for greater productivity and accountability, the director of Vocational Education applied the elements of IMS to form the Vocational Instructional Management System (VIMS). The VIMS process provides a framework to use in planning and organizing to assure excellence in Missouri's vocational education system by focusing greater attention on the management of teaching and learning. The instructor guide for this student reference incorporates the needed component parts to aid agriculture teachers in the implementation of VIMS.

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AGRICULTURAL STRUCTURES

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GLOSSARY Glossary-1

Lesson 1: Preparing a Plan

When building an agricultural structure, developing and understanding a simple construction drawing is the first step in actually producing the structure. The following lesson will outline the importance of developing a useable plan and explain how to develop a simple plan.

The Importance of Having a Good Plan

A plan is a drawing of a proposed structure containing a pictorial representation of the structure and information about it, such as the various dimensions of the structure and the placement of any doors or windows. Having and following a good plan will provide a useable structure that serves its intended purpose. A good plan will be well thought out before the actual building of the structure begins, thus providing an opportunity to design the structure to meet specific needs. Following a good plan saves time and money and allows an individual to avoid the difficulties associated with situations caused by a lack of careful forethought. A good plan is the builder's instruction sheet!

The Steps in Making a Good Plan

The first step in making a good plan is determining and defining needs. Being as specific as possible is important to avoid problems with the plan later. The person planning the structure should ask himself or herself, "What are the intended uses of the structure?" As she or he considers the uses of the structure, this information should be written down and reviewed carefully. For example, suppose storage space was needed for lawn and garden equipment, so a storage shed was to be built. The person putting together the plan would need to make the storage shed as usable as possible. A good place to start would be to write down a list of the items that would be stored there.

The next step is to determine the size of the structure. The designer should consider what size the structure needs to be to fulfill its intended purpose. Forethought is required at this point in the plan. Defining the needs is first evaluated by determining what the building is to be used for and considering any needs that might be designated in the future. Also, consideration must be given in order to have enough room in the structure for access and maneuvering. For this project, a storage shed with floor dimensions of 10 feet by 14 feet, equaling 140 square feet of floor space, should be sufficient for storing a riding lawn mower with a width of 42 inches, a wheelbarrow, and many hand tools and supplies. A door 48 inches wide and 80 inches tall centered in the front of the building would allow good entry for the equipment. Walls should be 8 feet in height with an overall building height of 18 feet from the ridge of the roof to the bottom of the structure.

The third step is to choose the style of the structure. Different styles and combinations of styles allow for a wide selection of structures. Structures are often referred to by their shape or roof style. Some examples of basic shapes are round, dome, A-frame, square, or rectangular. Common roof styles are gambrel, gable, or a shed roof. These roof types will be discussed in more detail in later lessons. For the storage shed described in the preceding paragraphs, a gambrel roof would be a good choice. This style will allow for considerable overhead room that can be used for storage if needed.

While other factors to think about at this point in the planning process will not affect all structures, they may be considerations in certain circumstances. An individual planning a building may need to consider the following factors:

- Material resources available - Some materials may be more cost efficient or easier to work with in construction but are simply not available or would take too long to find and purchase. An excellent example is very long pieces of dimensional lumber. Sixteen-foot lengths are not available in all dimensions on a regular basis; longer lengths may be very hard to obtain.
- Cost factors and constraints - Cost is usually a limiting factor in construction. Projects must be constructed at a cost that will allow for their completion and use.
- Building and fire codes - These codes provide a list of rules and regulations that must be followed when planning and constructing a building. The regulations do not just apply to residential buildings, but to most structures. Compliance with any code or regulation in effect for a structure makes good sense. They are designed to ensure structures are safe. Insurance companies may also reject

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insurance applications or certain claims on buildings that are not in compliance.

- Zoning laws - Zoning laws are a set of local restrictions and requirements that determine what type of building may be done in a particular area. These laws regulate the type of building permitted, the size of a structure, the permits required, the style of construction, and other characteristics.
- Insurance and/or financial stipulations - These stipulations can affect the style and size of building that a lending institution will approve for financing. If commercial financing by a bank or other lending agency is required for the project, insurance is commonly required also.
- Safety considerations for specific structures - Structures may have very specific safety concerns, which generally depend on the enterprise in question. Ventilation could be a serious safety consideration, as a repair shop where engine exhaust or fumes might build up to dangerous levels. Milking parlors that are washed down daily may have slick floors if special measures are not included in the plan before construction begins. Hay and grain storage facilities have specific fire precautions that need to be addressed before construction.
- Utility and service access - Any enterprise will need some level of utility and service access to structures, and some need very reliable access. A good example is dairies where milk must be picked up on a regular basis.
- Cleaning requirements - For some enterprises, such as dairies and pig nurseries, cleaning is an everyday practice. Drains and sufficient water supplies must be planned to operate efficiently.
- Heating and cooling requirements - These requirements are critical to some enterprises, such as greenhouses or livestock and poultry facilities. They must be planned before beginning to build a structure.

Notice how quickly details accumulate when putting together a plan. Even a simple drawing must convey a large amount of information. A simple construction drawing for the storage building described could be put together from the information given above. However, before the plan could actually be drawn, an understanding of scale and the symbols used on plans is necessary.

Scale

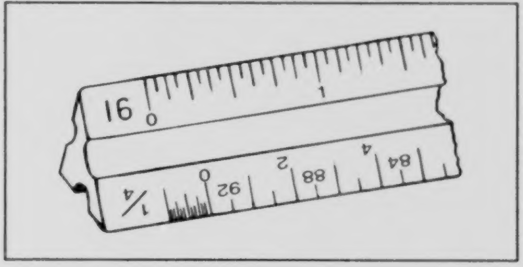
According to Webster's Dictionary, scale means "a proportion between two sets of dimensions." For plans, scale indicates an adjustment in the size of a drawing that reflects the size of the object being drawn. Drawing structures to their actual size on paper would not be practical. A system of reducing the actual size mathematically has been devised to compensate and allow for easy drawing and interpretation. An example would be to draw a construction project to 1/48 of the actual size, with one foot of the actual project being represented by ¼ inch on the drawing. This scale would be indicated on the drawing by including the following label: Scale ¼ inch = 1 foot.

Some common scales are used to represent projects of different sizes. Although many different scales can be used, the chart in Table 1.1 shows several of the most common scales. They are found on a triangular architect's scale (see Figure 1.1), a tool used by professionals who do many construction drawings. The architect's scale combines the eleven commonly used scales on one tool. Two scales are found on each face. The

Table 1.1 - Common Scales

Full Scale	
3/32" = 1'	⅛" = 1'
3/16" = 1'	¼" = 1'
⅜" = 1'	½" = 1'
¾" = 1'	1" = 1'
1½" = 1'	3" = 1'

Figure 1.1 - Triangular Architect's Scale



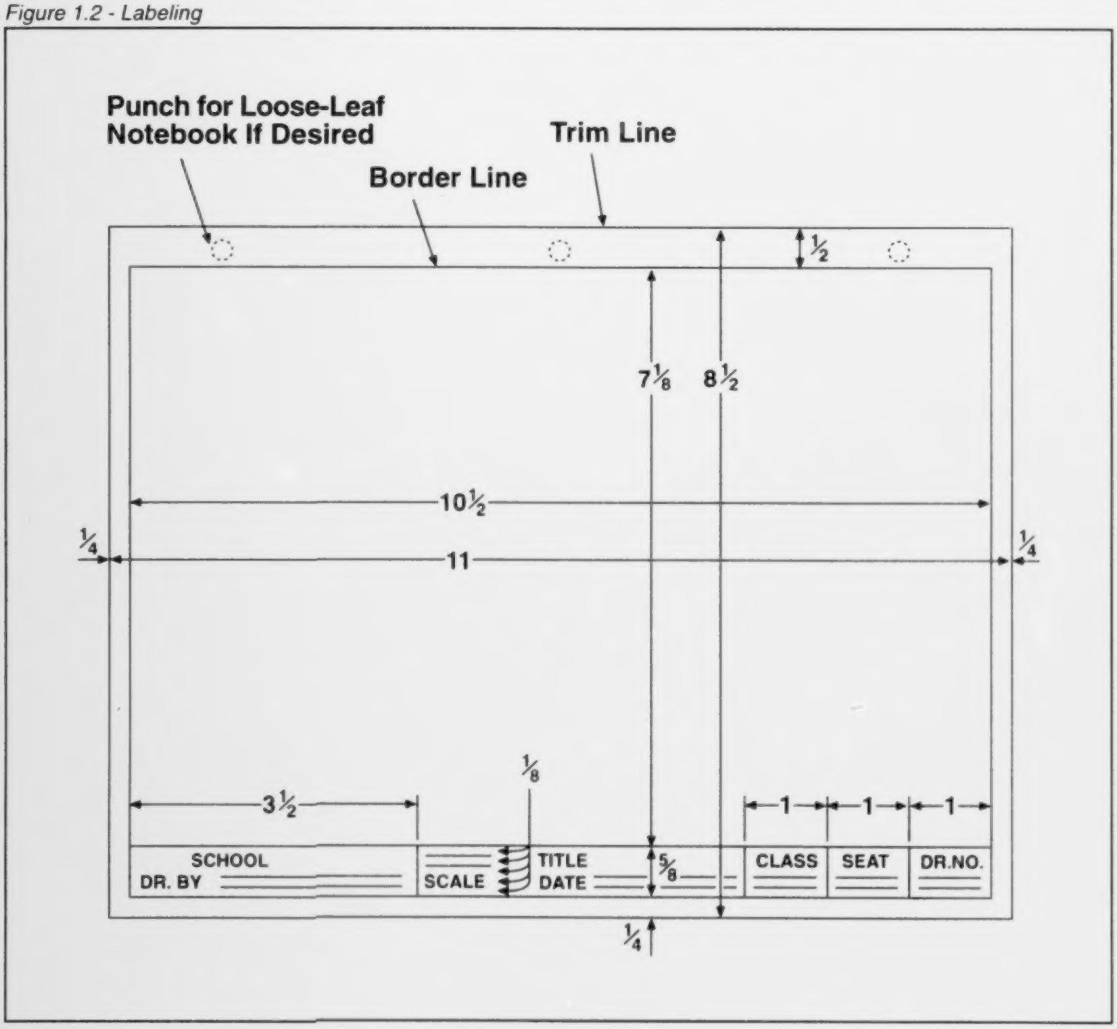
main units of the scales are undivided with a fully subdivided extra unit at the zero end; the only exception is the full size scale, which is divided into sixteenths. The numbers listed at the zero end represent the length in inches that will represent one foot of the actual structure being drawn. This tool is very convenient for anyone drawing by hand. However, a regular ruler may also be used to draw a simple plan to scale.

When using a regular ruler, consider the maximum amount of space available for drawing. If standard drawing paper is used, as shown in Figure 1.2, approximately 10 inches by 7 inches is available for the drawing. Then consider the size of the actual structure. The storage building described in the earlier example has a 10 foot by 14-foot floor. To draw this structure on a standard sheet of drawing paper, the scale must fit a length of 10 inches and a width of 7 inches. The scale must fit within 7 inches, since this measurement is the limiting dimension for the drawing. What is needed is a scale that represents 14 feet in no more than 7 inches of drawing space. Keep the math simple and estimate a scale that might work. If the scale ½ inch = 1 foot is used, 7 inches on the drawing will represent 14 feet of the actual structure.

Common Symbols and Elements of a Plan

Elements are the different parts of a construction drawing that convey information or enhance the information displayed on the drawing. Examples of elements would be all the information in the blocks provided in the title box, such as the name

Figure 1.2 - Labeling



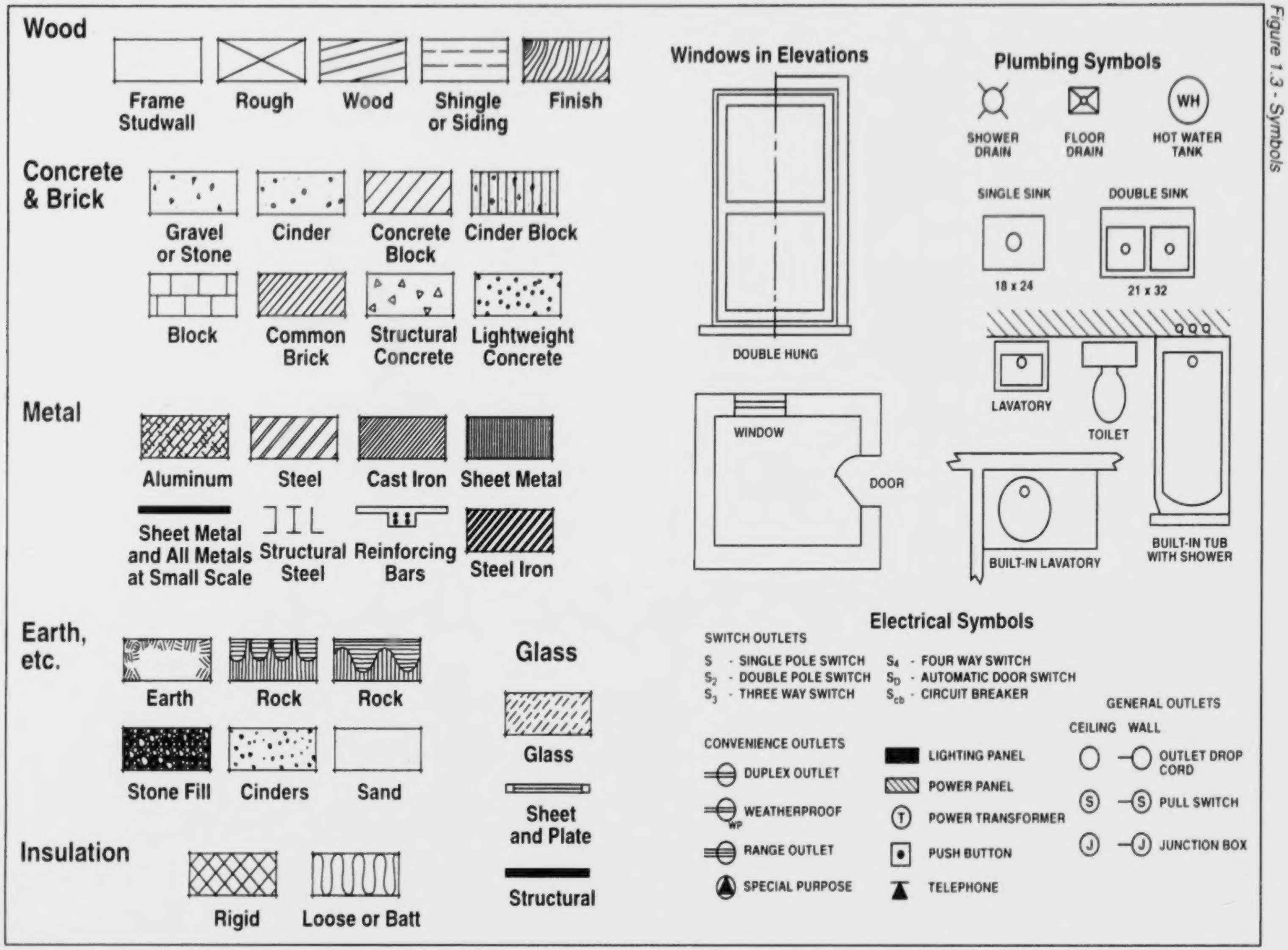

Wood
Frame Studwall
Rough
Wood
Shingle or Siding
Finish
Concrete & Brick
Gravel or Stone
Cinder
Concrete Block
Cinder Block
Block
Common Brick
Structural Concrete
Lightweight Concrete
Metal
Aluminum
Steel
Cast Iron
Sheet Metal
Sheet Metal and All Metals at Small Scale
Structural Steel
Reinforcing Bars
Steel Iron
Earth, etc.
Earth
Rock
Rock
Stone Fill
Cinders
Sand
Insulation
Rigid
Loose or Batt
Glass
Glass
Sheet and Plate
Structural
Windows in Elevations
DOUBLE HUNG
WINDOW
DOOR
Plumbing Symbols
SHOWER DRAIN
FLOOR DRAIN
WH
HOT WATER TANK
SINGLE SINK
18 x 24
DOUBLE SINK
21 x 32
LAVATORY
TOILET
BUILT-IN LAVATORY
BUILT-IN TUB WITH SHOWER
Electrical Symbols
SWITCH OUTLETS
S - SINGLE POLE SWITCH
S2 - DOUBLE POLE SWITCH
S3 - THREE WAY SWITCH
S4 - FOUR WAY SWITCH
SD - AUTOMATIC DOOR SWITCH
Scb - CIRCUIT BREAKER
CONVENIENCE OUTLETS
DUPLEX OUTLET
WEATHERPROOF
WP
RANGE OUTLET
SPECIAL PURPOSE
LIGHTING PANEL
POWER PANEL
T
POWER TRANSFORMER
PUSH BUTTON
TELEPHONE
GENERAL OUTLETS
CEILING
WALL
OUTLET DROP CORD
S
PULL SWITCH
J
JUNCTION BOX

Figure 1.3 - Symbols

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of the person drawing the plan, title of the project, date, and scale (see Figure 1.2), as well as the symbols found on the drawing. The lines used for the drawing are also elements of a plan.

Symbols are pictorial representations of information that are included on the actual drawing. Some symbols, such as those for doors and windows, may be subject to the same scale as the rest of the drawing. They show the location of these parts of the structure. Other symbols, such as those used for plumbing and electricity, show where these devices or appliances are to be located. Symbols may also indicate the type or grade of materials used, such as concrete, steel, or wood.

The symbols that can be included on a plan cover a large number of pictorial representations of items that should be shown but are not practical to draw. As the illustration of symbols shown in Figure 1.3 indicates, they can be broken into categories, such as electrical symbols, plumbing symbols, symbols for metals, and symbols for lumber.

Symbols are most often used on plans to represent specific types of materials, doors, windows, and electrical or plumbing apparatuses. They need to appear on the plan where the specific information they convey is important. The appearance of symbols may vary between different sources, but they generally are like the examples in the illustration or are similar enough to be recognizable. Symbols are a great convenience for displaying information. The information conveyed by most symbols is more often of use on detailed plans. These symbols may appear on simple construction drawings if they are needed to represent specific information related to a particular plan.

Several different types of lines (Figure 1.4) may be used on a plan. As with the symbols, using all these lines on a single project is unlikely, but each may convey information needed for a specific project.

- Border line - A border line is the heavy dark line around the perimeter of the drawing paper, usually ¼ inch from the paper's edge. The drawing and all other information are inside the border line.
- Object line - This line is a very distinct line used to draw the object.
- Hidden line - A hidden line is a dashed line that represents material in a drawing that is under other material from the view being displayed.
- Extension line - This type of line is used for placing dimensions on drawings. It extends from objects without touching them to indicate their length, width, and height.
- Dimension line - This line shows the size of an object. It spans the space from one extension line to the next and has arrows at each end; a numerical notation of the length is displayed in a broken area in the middle of the line.
- Break line - A break line represents an area in a structure where a section has been removed.
- Cutting plane - A cutting plane shows an area where a section has been removed. Arrows on the end show the direction from which the section was taken.
- Center line - A center line shows the centers of holes and round shapes, such as drains.

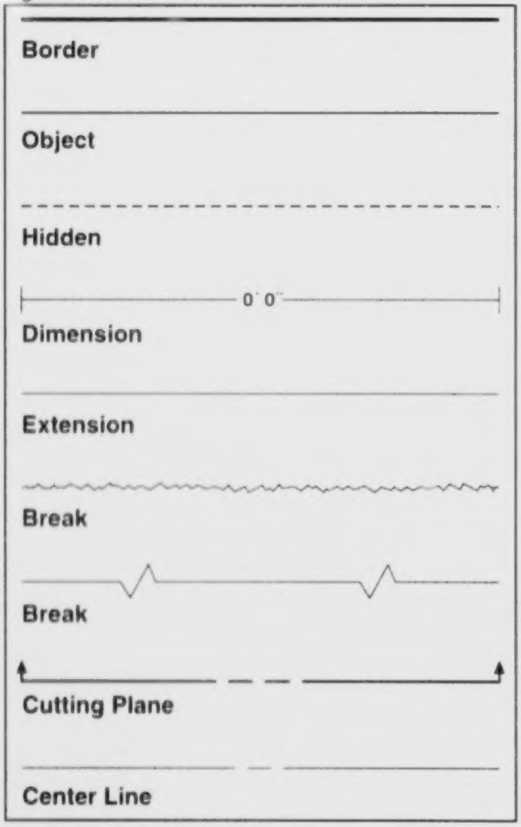
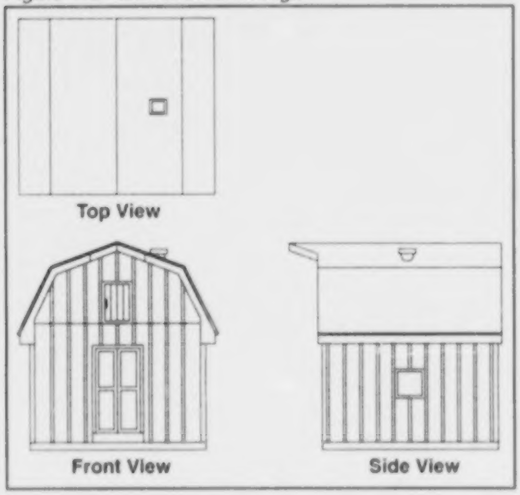


Figure 1.4 - Lines

Elevation drawing is a term used by drafters to refer to orthographic projections of a structure as viewed from different perspectives, most commonly the top, front, and one or both sides. Drawing only one view simply does not provide enough information to be able to visualize the structure completely. To convey the necessary basic information about a structure, a minimum of three elevation drawings must be produced either by hand or with a CAD system. These drawings show the exterior features of the building. Figure 1.5 shows different elevation drawings for a particular structure.

Figure 1.5 - Elevation Drawings



Computer-Aided Drafting

Computer-aided drafting or design, called CAD, is a system consisting of a computer and specially designed software that does the actual drawing of plans. CAD software programs are offered in different levels of complexity as well as in home versions that are inexpensive and produce excellent results. CAD is now the industry standard for drafting. The four main benefits of CAD over conventional hand drafting are speed, quality, ease of making changes, and communication (since CAD drawings can be transferred electronically). Drafting complex plans was once very labor intensive but can now be done with less effort. Changes can be made and viewed easily before printing. However, the CAD operator must still have the skill and talent to develop a functional plan. Many schools now teach the use of CAD.

Summary

As demonstrated throughout the lesson, the plan affects how the structure ultimately looks. To formulate and produce a good plan, the structure's intended purpose must be carefully considered. Decisions on style and size are determined by evaluating all known facts concerning the proposed structure. Each structure will likely have its own unique circumstances and considerations that factor into the plan. To convey the necessary information, a minimum of three elevation drawings of the structure must be produced either by hand or with a CAD system.

Credits

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Lesson 2: Understanding a Plan of Procedure

This lesson will provide information about how to develop a plan of procedure and produce material lists, also called bills of materials. Different types of material lists and their uses will also be explored.

Steps in Making a Plan of Procedure

A plan of procedure is the order in which everything concerning the eventual completion of a planned project is identified, listed, and then arranged in a logical order from the first step to the last step. A good place to start is with a review of the printed construction plan. From this, the exact material requirements can be determined.

A good plan will need to follow a logical order suitable for the project. The first step in developing a plan of procedure is identifying every factor that may affect the project and then arranging all the identified elements in a logical order. With some projects, this process may be lengthy. Factors such as code specifications, site, financing stipulations, and insurance requirements can affect some plans of procedure. More complicated structures might require extensive site preparation before construction of the foundation, or perhaps utilities must be placed before concrete is poured. A variety of circumstances and situations may need to be considered. A good plan requires careful attention and forethought. Visualizing and writing out each step of the project's construction can be of value in formulating a plan.

The second step in developing a plan of procedure is considering the type and grade of materials appropriate for the project. Each project may have unique circumstances that might influence these choices. The person doing the planning must evaluate the purpose of the structure and select materials with this information in mind. Other factors to be considered are resources and their availability. Materials come in a variety of grades of quality, each of which is suited to a specific set of circumstances. Retailers of specific products are knowledgeable and can be of help in selecting materials for construction.

The third step in the planning process is putting together a list of the materials required. This type of list is called a bill of materials. This list will need to be developed from the information assembled so far and by studying the plan drawings.

The final step involves the purchase of materials and the assembly of the structure. After the needed materials have been bought, any necessary cutting of the materials is done. The project can then be assembled in a logical order.

The Importance of a Bill of Materials

A bill of materials is a list of all the components included in a proposed project. The materials need to be identified by amount, size, and kind. Also, for convenience, they are usually separated into broad categories of supplies, such as lumber, plumbing materials, electrical materials, etc. These lists are necessary for purchasing the correct amount of materials and for obtaining cost estimates. For projects requiring a significant amount of materials, a common practice is to submit a bill of materials to different suppliers and receive quotes on the exact cost from each supplier. These estimates can vary considerably.

Cutting and Purchasing Bills of Materials

Bills of materials are often divided into two types of lists, a cutting bill of materials and a purchasing bill of materials. Many materials used in construction of agriculture structures come from suppliers in standard sizes and dimensions, particularly plumbing supplies and lumber. These standard sizes make it necessary to purchase more material than will be used in the project. The materials are then cut to the exact dimensions needed during construction. Careful consideration must be given to the purchase of materials to minimize waste and keep costs as low as possible.

A cutting bill of materials is a list of all the materials, in the actual sizes or dimensions needed, that will need to be cut to size during the construction of the project. For most projects, depending on the material type and size of the project, the cutting list is developed before the purchasing list to reduce waste when purchasing materials.

The purchasing bill of materials can be developed from the information identified in the cutting bill of materials and from the drawings of a structure. This list should include the materials identified on the cutting bill of materials in their standard sizes.

It will also list all other materials needed to construct the project, such as fasteners, hinges, wire, etc.

The following example illustrates developing a plan of procedure with a cutting and purchasing bill of materials. The selected example is a sawhorse, illustrated in Figure 2.1. Developing a plan of procedure involves first studying the elevation drawings and noting the dimension lines to determine the details of the project.

As noted on the drawings, the project consists of 2" × 4" boards in different lengths, two sections of 1" × 6" board, and screws for fasteners. Wood is the material used for this project. The next step of the process is to inventory the parts of the project and develop a cutting bill of materials.

Inventory:

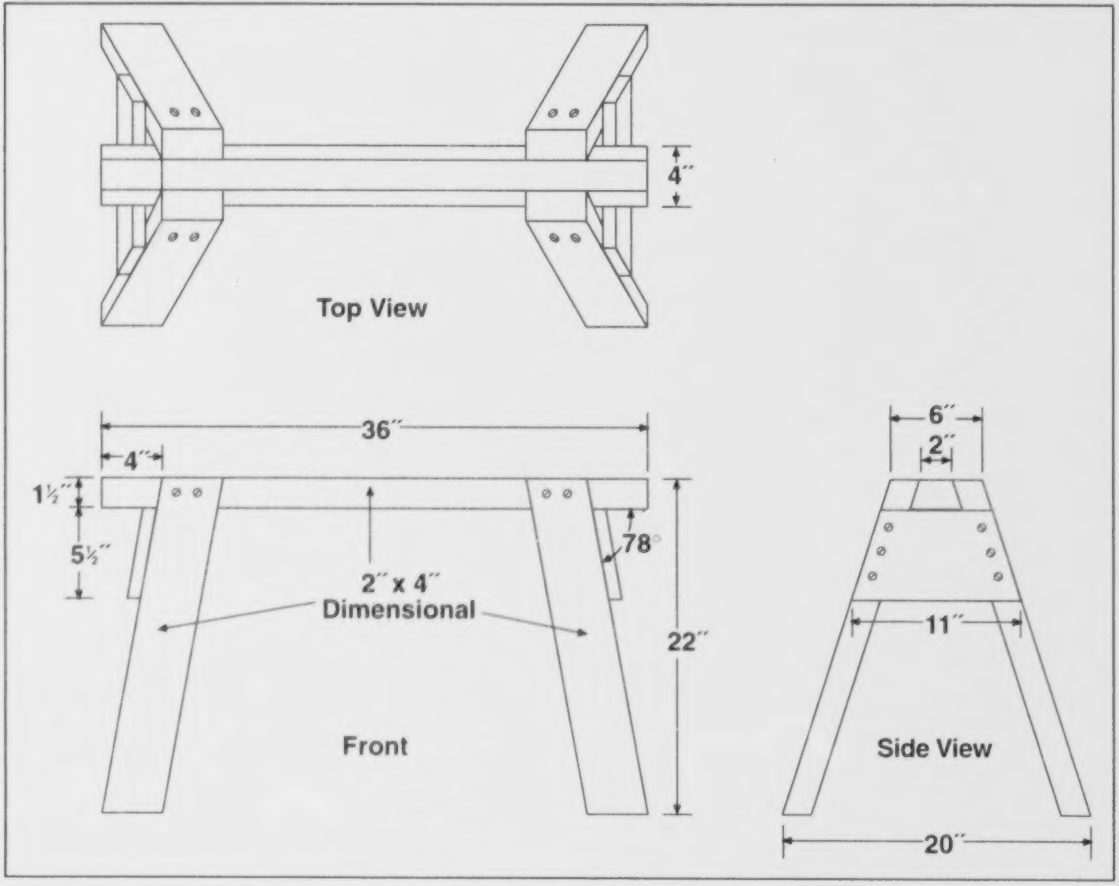
Top - 36-inch length of 2" × 4" material
Legs (4) - 22-inch length of 2" × 4" material (totaling 88 inches in length)
End braces (2) - 11-inch length of 1" × 6" material (totaling 22 inches in length)
Wood screws - Eight 3-inch screws and twelve 1½-inch screws

Cutting bill of materials:

One 2" × 4" board, 36 inches in length
Four 2" × 4" boards, 22 inches in length
Two 1" × 6" boards, 11 inches in length

The purchasing bill of materials can now be composed from the above information, keeping in mind the need to minimize waste and the standard sizes of lumber. A total of 124 inches of 2" × 4" lumber is needed (36 inches for the top plus 88 inches for the legs). Lumber is available starting at 8 feet in length and increasing in increments of two feet, so one 12-foot (144-inch) board will provide enough material for the project with a 20-

Figure 2.1 - Sawhorse



inch section left over. The end braces consist of 1" × 6" lumber, and although a total of only 22 inches is required for the project, the purchase of a standard 8-foot board will usually be necessary. The remainder, a section 74 inches in length, can be used for a future project. Wood screws will be used to assemble this project, requiring eight 3-inch general purpose wood screws and twelve 1½-inch general purpose wood screws. To complete this project, the materials should be purchased. They can then be cut to size and assembled.

Purchasing bill of materials:

Eight 3-inch wood screws
Twelve 1½-inch wood screws
One 2" × 4" board, 12 feet in length
One 1" × 6" board, 8 feet in length

Summary

This lesson outlines four basic steps that can be applied to agricultural structures to develop a plan of procedure. By following the steps carefully, precise material needs can be determined to successfully complete a project from beginning to end.

Credits

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Lesson 1: Home Site Selection

Whenever the construction of a new home is planned, the site must be evaluated before building. If the site is not carefully chosen, the home owner may experience problems later. The structure may not be of as good a quality as possible or may be more expensive than necessary.

Soil and Water Conditions

As a part of home site selection, the soil conditions on the property need to be considered. The bedrock depth and soil type will affect foundation design decisions. A test should be done to determine the depth of bedrock formations or the underlying soil conditions at possible sites.

Any site with surface and subsurface water for more than half the year should be avoided if possible. A building site will be easier to work with and on if the location selected does not have subsurface water. Subsurface water makes concrete work more difficult by increasing the moisture level in the concrete. It also makes sealing the building difficult, which will lead to water in the basement or crawl space. Eventually, subsurface water leads to mold, mildew, or rot in wood buildings. If an entire plot has subsurface water, a drainage system may possibly be installed to remove the excess water.

Topography

Topography can be defined as the relative positions and elevations of the natural or man-made features of an area that determine the surface configuration of the land. For site selection purposes, this is simply defined as how the land lays. Topography will greatly impact construction if the selected site is on an uphill or downhill slope. Consideration must also be given to the topography that surrounds the selected site as this will determine how water and wind moves toward and away from the site.

Hillside construction will have higher costs because the need for retaining walls, grading, fill material, and general site preparation are greater in comparison to a flat site. Considerable amounts of soil may need to be either removed or brought onto the site to make it useable. This process will require additional advance planning in securing a place to deposit excavated dirt or finding a source for dirt or proper fill material.

Topography is also important because of water runoff. Building a house at the bottom of a hill means that water will run down toward the house, possibly causing flooding or sub-irrigation problems. In addition, the location of other facilities can be a factor when considering runoff. If a livestock lot is located uphill from a proposed home site, liquid waste may run downhill toward the home and contaminate water resources. A home site should generally be located on a higher elevation than livestock facilities or crop ground where many chemicals are used in order to allow the water runoff to flow away from the site.

The amount of wind that strikes the home is affected by topography. Homes built on hilltops or knolls generally receive more wind than those built on hillsides or at the base of hills. Natural growing trees or man-made windrows can provide protection from wind, but the topography may limit natural growth or make new trees hard to establish. Additional construction costs may be incurred to insulate and strengthen roofs and walls that are exposed to heavy prevailing winds.

A factor that should be considered is if the location offers the possibility of expansion. If an addition onto the building (such as extra rooms, a garage, workshops, etc.) may some day be necessary, careful consideration should be given to the initial site chosen for the building. Room needs to be left around the building, especially on those sides where additions may be built.

One of the most overlooked factors is the building perspective, or view. Building perspective is the direction a building faces in relation to the external scenery. If a scenic view is desired and offered by a certain direction, the view must be considered in laying out the building. The location of the larger windows, such as the large picture windows in the living room or kitchen of a house, is of particular importance.

Wind

In addition to affecting the choice of a location for the house, wind will affect how a house is laid out. If possible, the main entrance is commonly located on a side of the house away from prevailing winds. For example, in an area with strong north winds, the main entrance may be on the south side of a building. If the door faces the direction of the prevailing winds, rain, dust, and debris may blow into the house, and the wind may cause damage when the door is opened. Snow drifts can also accumulate around the door and may make it inaccessible.

Services and Utilities

Every new building requires certain services and utilities, and houses are no exception. Every house must have road access, a water source, and sewage facilities, as well as electrical power, telephone service, and possibly natural gas or propane for heating and cooking. The site chosen for a home should take into consideration the ease with which these utilities and services can be provided.

The distance to services and utilities should be considered because it will affect the cost of bringing them to the home. It is desirable to build as close to existing roads and utility lines as possible, especially electricity, telephone, and gas lines, to keep costs at a minimum. If the closest access is found at one corner of the property, the home may be placed closer to that corner because the cost of installing these services over a long distance can be considerable. The local electrical power, telephone service, and natural gas suppliers may be contacted to determine the cost of extending power, telephone, and gas lines to the home site.

If the location of the utilities is unknown, locator services can come to the property to determine the location of various utilities. Using a locator service may also reveal that some of the utilities already cross the property, which would probably lower the cost, especially with gas lines. By planning utility access, the builder can budget for the costs of bringing the utility to the building, especially if power poles, trenches, conduits, or other items are needed.

Many rural homes make use of propane gas for heating or cooking. Tanks should be located so as not to detract from the home's appearance, yet they should be easily accessible for the propane supplier to refill. Propane suppliers will provide tanks, meters, and trenched-in connecting lines for an initial lease fee for their customers. Suppliers may also provide footing blocks, or the home builder can pour a level concrete pad to set the tank on. Home owners are required to provide a stubbed-up exterior line that is securely capped or connected to the heating system and/or appliances.

Drilling a well is often necessary for rural homes in order to secure a good water supply. State law requires all wells used for drinking water to be drilled to at least 80 feet to prevent groundwater runoff from directly entering the system. Knowing the average depth of drilling to reach quality water prior to selecting the site may influence selection because drilling costs are based on the number of feet drilled and the soil structure where the drilling will be done. The depth of the well can vary greatly in different areas. In Boone County, Missouri, good water sources can be reached at 80 feet, but in nearby Howard County, wells generally need to be drilled to 250 to 400 feet. In Howard County, drilling through hard rock to install a six to eight inch well casing would currently cost approximately $900 to $1,500, not including the cost of a submersible pump or the pipe line and trenching from the well to the home. To determine the approximate drilling depth, homeowners should contact the Missouri Department of Natural Resources, Division of Geology and Land Services, for information about water availability and location.

Several rural areas throughout the state have access to rural water districts. Water is purchased and piped from a nearby town or city's reservoir or well system. A homeowner can hook into this system for an initial fee and then purchase water based on usage on a monthly basis. Using a rural water district may be more cost efficient than drilling a well if the distance to the connection is fairly close and if the topography presents no major obstacles. Livestock and crop producers may still consider drilling a less expensive well for farm use in addition to using rural water.

Sewer service is seldom available outside city limits. If it is not, the builder will need to arrange for a private sewage disposal system to be constructed. A large area of land and suitable soil is necessary to prevent contamination of surface water and wells. Septic systems should be located away from home and building sites. Local or county sewer regulations should be consulted before building to determine if a site is acceptable. Many counties will not allow a septic tank or sewer field to be placed within a certain distance of rivers or ponds.

Access to the site for concrete, lumber, and other material deliveries is important for construction. Consideration should be given to where the roads currently are and where they will need to be built on the property to provide access. Roads and room for turning around should be provided. Time should be taken to consider where a lawn or any other landscaping will be prior to laying out the roads. Geomat, a mesh material, is commonly placed on the ground to provide traction for vehicles if the site is wet and muddy. Bridges may need to be added to allow access for trucks and other vehicles.

Regulatory Agencies

Generally, more agencies will affect construction within city limits than in rural areas. In many communities, fire codes and local building codes that set guidelines for building need to be taken into account when planning a structure. For example, fire codes may specify the distance from other buildings necessary to provide fire trucks and other emergency equipment access to the site. Common building codes include regulations for the reinforcement of concrete structures, service access, and utility access. An inspection is often required prior to beginning the project to make sure the building will be constructed according to code. For information about the codes for a particular area, the local building inspector or county commission can be contacted.

Zoning laws may also affect construction. Many communities have zoning laws that prohibit the construction of private homes in areas that have been zoned for commercial development. The local zoning commission, building inspector, or assessor can usually identify local zoning laws that apply to the site being considered.

In a rural area, builders may only need to obtain permission for construction from a county board of commissioners. The amount of regulation will depend on the local area, however. In some places, sewer fields must be approved prior to construction, generally by a local or county sanitation board. Zoning laws have also become much more common in many agricultural areas.

Neighbors

As more homes are built in rural areas, the issue of neighbors becomes more relevant. The location of neighboring homes can impact the selection of a building site for a home. Some landowners choose to build the home as far as possible from other neighbors to obtain greater privacy. However, if neighbors are also relatives, some home builders may select a site that is relatively close to neighboring homes. This practice may allow for more family interaction and promote a greater sense of security.

Having the Home and Business on the Same Site

A number of issues must be considered when building a home on a business site, as is commonly the case in agricultural situations. If the home is located on the site, the possible sale of the home at a later time needs to be considered. Many owners choose to sell an existing home to finance the construction of a new one. If the home is in the center of some type of business site, it may be difficult or impractical to sell. If the home is located on the edge of the property separate from the business, selling the home will be easier but will require accepting new and closer neighbors. Also, road access to the farming or business operation may have to be added, as well as connections to services and utilities.

Another reason builders should consider the possibility of locating the home in an area away from business activities is because excessive noise, traffic, or pollution may be a problem. Odors, fumes, dust, and other problems are not desirable and can be a health concern at the home site.

Having the home site near the business operation may also pose potential safety problems for the residents, especially children. Agricultural operations use numerous pieces of equipment that are dangerous. They can be even more dangerous to children, who may not realize how to protect themselves. Many people prefer to locate the home away from more hazardous activities to help ensure the safety of children and visitors.

Environmental Concerns

Environmental concerns are very important when selecting a site for a home. Before a site is chosen, a number of environmental issues should be considered. An environmental audit (definition) examines the potential building site to determine if any environmental issues will need to be addressed prior to construction. An environmental audit can alert home builders to a number of potential hazards and what measures can be taken to eliminate any problems.

Several potential problems may exist that can be determined through an audit. One of the most significant environmental and safety problems is the existence of abandoned wells, especially on old farmstead sites. As new drilling techniques and regulations have come into use, many old rock wells have been abandoned or even used to dispose of hazardous liquids. Even modern wells have been abandoned for rural water connections. Their locations are seldom recorded, and often these well openings are hidden by natural overgrowth until they are discovered, sometimes through dangerous accidents. A thorough environmental audit can help identify any abandoned wells through a study of county records of the property and a physical evaluation of the site. Other potential problems that should be considered are the identification of underground storage tanks, old landfills, or dump sites. Underground tanks may have held substances like gasoline or diesel fuel, and landfills or dump sites could contain chemicals that are harmful to humans if they get into the drinking water.

Summary

When considering the selection of a site for a home, a number of issues should be addressed, including topography, wind, services and utilities, regulatory agencies, neighbors, locating the home and a business on the same site, and environmental audits. By carefully considering each of these factors before selecting a site for construction, problems can be avoided in the future.

Credits

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Lesson 2: Arranging a Farmstead

A farmstead can be defined as a farm and its structures. Preparing a farmstead plan involves many variables and complexities. Developing a good plan requires considerable forethought and effort. This lesson outlines major considerations in farmstead planning and will show how to systematically address issues. Also, long-term goals must be kept in mind from the beginning to achieve the desired results. A good farmstead plan will involve research and outside help. Local University Extension offices are an excellent source of information and referrals.

Direction of Farmstead Layout

Farmstead planning often involves orienting activities in relation to one another and the farm's effect on surrounding areas. Efficiency of farm operation is a key to farmstead planning. To be efficient, a farm will have to be laid out in a convenient fashion. Structures associated with related activities, such as feed storage facilities and feed lots, should be located near one another. In addition, the noise, dust, pollution, and insects associated with agricultural activities must be anticipated and directed away from residential areas, which can be a challenging proposition. These conditions occur to some degree in most farm enterprises, but if they are taken into account during planning, detrimental effects can generally be minimized. However, if a farm is the source of significant amounts of noise, dust, pollution, or insects, locating activities at a suitable distance from residential areas may be the only choice.

Orientation of structures according to the four directions is usually done to minimize the effects or take advantage of natural elements such as sun or a prevailing wind. Orientation of individual buildings is a function of the type of building, type of enterprise, and desired outcome of the structure's use. An example of this type of planning would be orienting a greenhouse with a large translucent wall to the south to gain extra sunlight or positioning a milking parlor with milk storage tanks receiving the least southern exposure possible to avoid sunlight, which will heat the tanks.

Topography

The actual topography of a large area would be very difficult, and perhaps impossible, to change, so a successful farmstead plan must take advantage of the resources and options to which the available topography lends itself. Drainage, the removal or flow of water from an area, and pollution are of particular concern when considering topography. Addressing these concerns in the planning stages is critical to an operation's success. For example, drainage of water from rain, snow, ice melt, or farm operations should be away from structures, with a slope of 3 to 5 percent. As water passes over the ground, it may erode soil; a slope of 3 to 5 percent will allow for drainage without promoting erosion. Water can also damage structures if allowed to drain into them, which is why a slope away from structures is advisable.

Pollution that may enter the watershed from agricultural enterprises must be managed. Exactly what constitutes a pollutant and what management practices will be required are generally governed by law and are specified in codes and regulations concerning specific enterprises and their by-products. Topography plays an essential role in pollution control in that understanding a given area's topography will provide an understanding of the direction and routes of drainage. Structures such as dams, holding ponds, or routing channels are sometimes effective in controlling the effects of pollution in a given area.

Topography is also a significant factor in regard to accessibility for machinery, water retention, and soil components. To some extent, topography explains why similar farm enterprises are located in similar geographic regions. Often, the reasonable uses of a property are limited or more adapted to a particular type of enterprise because of the topography of the area. An example would be marshy areas that may support rice production, but little else. Whatever the type of enterprise, the topography must be able to support the operation's activities profitably. A row crop operation will require relatively flat land with few stones. On the other hand, beef cattle operations may work well in a hilly, rocky area.

Wind

Wind erosion can be a significant factor in many farm enterprises, especially field crop enterprises.

Historically, wind erosion has been devastating to farmsteads in susceptible areas. Preventing wind erosion may be impossible. Wind breaks are a key to success in dealing with wind erosion. Most wind breaks are rows of trees strategically planted and spaced to interrupt a prevailing wind. While they are helpful, establishing wind breaks is usually time consuming. Effective wind breaks need very careful planning; consulting an agricultural engineer is recommended if a large wind break is needed. Orienting a structure to act as a wind break is helpful in shielding small areas from a prevailing wind. For example, locating cattle holding areas on the side of a barn or milking parlor away from winds provides shelter for the animals.

Wind must also be considered when planning for enterprises that involve odors or airborne contaminants. Residential areas need to be protected from both of these problems. If the farmstead in question has a prevailing consistent wind, devising plans to address airborne contaminants may be easier. Such winds can be an advantage if they blow away from an area where windborne contaminants may cause problems. However, if a prevailing wind is carrying contaminants into an inappropriate area, the most effective solution is to locate the source of the odors or contaminants at a distance from other activities. Consulting with an agricultural engineer experienced in these issues may also provide aid in determining options. These problems may be controlled somewhat through the use of specifically designed ventilation systems and filters as well as regular cleaning and good waste management practices.

Heating and cooling requirements are affected by wind. Prevailing winter winds from the north are of considerable concern when evaluating heating requirements. Reducing the number of windows or their size on the north side of structures and taking advantage of wind breaks can be of help in reducing heating needs. Orienting farm structures to take advantage of wind for ventilation can help in meeting cooling requirements as well as enhancing livestock health.

Natural Resources and Environmental Impact

Natural resources are material sources of wealth that occur in a natural state, such as timber, water, or mineral deposits. Taking advantage of the natural resources an area provides is advantageous to farming operations. However, natural resources must be used in compliance with the regulations governing their use. These laws are designed to protect the environment and its inhabitants. Complying with these regulations can be complicated. The codes and regulations are constantly changing and evolving as the U.S. government becomes more and more involved in meeting concerns for public and environmental health. As a result, many agencies have been formed to monitor and ensure compliance with environmental regulations.

This focus on regulations greatly affects farmstead planning. Agricultural production has become a highly industrialized activity that involves countless chemicals and waste products, which makes agricultural operations subject to many regulations. These items all have the potential to damage the environment if misused. Generally speaking, any fuel, waste products, or chemicals used in amounts considered to be at a commercial level will be regulated. Each enterprise will have different circumstances, which will affect its regulatory requirements. Of particular concern is any contaminant that can enter and be spread in the watershed, contaminating valuable natural resources.

Type and Size of Business

Agriculture is a varied industry, and specific circumstances require individual consideration. The type and size of business affects many aspects of farmstead planning. It directly influences farm acreage needs, the number and type of structures required, the number and type of regulations affecting the operation, financing options, the source and amount of water, and waste management.

Farm acreage needs - Different enterprises require acreage suitable for their needs. Each enterprise's needs are different. A beef cattle operation may require hundreds of acres, while a greenhouse may only need half an acre. Careful consideration of future needs must take place during the first stages of planning if possible. The planner must think about what the operation might be like in 20 or 40 years.

Number and type of structures - The number and type of structures on a farmstead also must be adapted to the specific operation's needs. No one structure will meet every need. When planning a farmstead, an individual must do research to find information concerning the type of structures needed for a particular operation. Trade associations dealing with a particular type of enterprise are a good place to start asking questions. University Extension services may also be an excellent resource. Contract producers in the swine or poultry industries work closely with the processors with whom they contract to develop plans for farmsteads and structures designed for efficient operation.

Number and type of regulations - Research is required to determine what regulations might affect each aspect of the farmstead being planned. A county planning and zoning office would be an excellent place to begin a search for information. County Extension offices are also a good place to start. The planner will likely be referred to other agencies that deal with more specific details concerning the farmstead's planned operations. As a rule, larger operations require more and larger structures and produce more waste. They are therefore subject to more regulations.

Financing options - Because agricultural enterprises are generally businesses requiring a profit to be successful, financing options are critical. Agricultural operations have been lost to foreclosures and bankruptcies. Structures are expensive to construct and maintain, so careful planning is required when determining structural needs. Obtaining professional advice concerning farm financing is recommended. In areas where agricultural enterprises are common, professional accountants experienced in financing should be available.

Sources and amount of water - All farm enterprises require some amount of water. Many of them can require very large amounts, such as irrigated crop enterprises or large dairy operations. Water needs should be anticipated and evaluated in the planning stage. Often, water needs are greater than first expected, so careful research is required. The types of water sources, such as rivers, creeks, ponds, wells, and municipal water, and amounts they can deliver must be considered as well. Planning for structures should take into account convenient access to water supplies and drainage of wastes away from water sources. Laws and regulations may affect the options for water for the operation.

Waste management - Waste management must be planned according to the codes and regulations governing the enterprise. This area of farmstead planning is often a complicated one. Waste management structures such as holding tanks or lagoons are critical for the environment and must be planned carefully. The failure of these structures can lead to extensive damages for which the operator is liable. Lesson 2 of this unit contains more information about this topic.

Services and Utilities

Both the services and utilities available must be taken into account during farmstead planning. Utilities of an acceptable level and dependability must be available at a cost that will allow profitable operation of the chosen enterprise. Services that affect the particular enterprise in question must be available and consistent enough to allow profitable operation. Utilities and services include electricity, passable roads, fire protection, ambulance services, and telephone services.

Depending on the type of enterprise involved, the utilities and services needed can be extensive, and they may be critical to the success of the business. Two good examples are dairy and greenhouse enterprises. Power outages at milk times can be disastrous, as can an access road that the milk truck cannot use. Loss of heat to greenhouses during cold weather can devastate the entire inventory of plants.

Utilities and services must be considered when arranging the layout of structures. Overhead electrical lines should be located away from trees if possible, since falling limbs may break lines; underground lines tend to be more dependable. If water is supplied by a municipal source, structures must have suitable hookup access.

Planning for Neighbors

Laws and regulations, particularly zoning laws, will dictate much of what is acceptable when planning in regard to the neighborhood surrounding the farmstead. Most new agricultural enterprises will be required to locate in areas approved for these types of businesses. The potential for zoning changes and urban encroachment in the future should also be taken into account. If such changes are a possibility, the farm's operations may not be allowed to continue, and structures may have to stand unused. Some other concerns need to be considered, such as pollution and runoff that may affect neighbors, especially when planning structures that involve or alter watershed activity. For example, clearing timbered acreage to build a structure on a hill above a neighbor's home will create a greater amount of runoff, with the potential to damage a neighbor's home. Fences that separate properties and are used by both parties are worthy of consideration when forming a farmstead plan; agreeing on which party maintains the fencing may be important.

Regulatory Agencies

Regulatory agencies that are designed to protect the environment, its inhabitants, and natural resources have a direct effect on most farm enterprises. Compliance with regulations for such things as pollution control can be costly and involve considerable labor. Regulations may limit the size an enterprise can operate at successfully. However, they also work to ensure that the environment is safe for everyone. Two major regulatory agencies that provide guidelines and answers to questions for farmstead planning are the Environmental Protection Agency (EPA) and the Department of Natural Resources (DNR). State branches of these offices are excellent sources of information and will in most cases be an excellent place to start as well as a good source of referrals. Although this subject is large and complicated, resources to aid in understanding these regulations are readily available from the sources mentioned in the lesson as well as many specific subgroups of these agencies. The local planning and zoning office may also provide answers to many questions, and the staff may have current recommendations for sources of information on anything that is out of their scope of expertise.

Summary

When planning a farmstead, developing a good plan can be accomplished by listing the desired facts concerning the proposed enterprise. The size and type of business and its specific needs must be defined. Factors such as the direction of layout, topography, wind, natural resources, utilities and services, and location of neighbors are another consideration. Compliance with regulatory agencies may have a great effect on farmstead planning.

Credits

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Lesson 3: Livestock Manure Management Systems

Everyone involved in farmstead planning for livestock operations needs a basic knowledge of manure management. Acceptable management practices are dependent on factors such as the size and type of operation and soil conditions. Research into the requirements for the use of manure is therefore imperative for each livestock operation.

Principles of a Manure Management System

Animal manure contains materials, including nitrogen and, to a lesser degree, phosphorus, that can be harmful when concentrated in large quantities. Effective manure management is required for any operation to manage these substances, but with the development of larger operations, particularly in the beef, dairy, swine, and poultry industries, the complications of dealing with large amounts of manure have increased. The potential for manure to enter surface and ground water is, in most circumstances, the greatest threat, and the main goal of manure management systems is to prevent this type of pollution.

A manure management system generally consists of some sort of manure storage and handling. For livestock operations in which the animals are kept on a well-maintained pasture, manure storage and handling is generally not an issue, because the livestock manure is spread throughout the pasture. However, when animals are kept on lots or in some sort of confinement system, the manure that they produce must be handled efficiently to avoid pollution, maintain sanitation, and make use of the nutrients in the manure for fertilizer. Producers have a number of options for managing manure; the methods chosen will depend on the conditions of the livestock operation. Common storage options include pits underneath buildings with slotted floors, storage tanks, and lagoons. Common methods for applying the manure to fields as fertilizer include pumping it through irrigation systems and applying it to the land using some type of mechanical spreader.

The exact type of manure disposal system needed will be dictated by many factors, such as the size and type of enterprise, its location, costs, local zoning regulations, the volume, odor considerations, proximity of neighbors, and use of manure as fertilizer for crops. While the type of system or practices that will be required to operate successfully will vary, most systems are strictly regulated to protect the environment.

Regulatory Agencies Involved in Manure Management

The number of agencies and specific divisions of agencies that are involved in livestock manure management is growing and evolving as the issue of handling manure effectively becomes more critical. Help can be obtained from the following agencies at the federal, state, and local levels; referrals from these agencies will lead to answers for most questions. Most of these agencies also make information available on the World Wide Web.

Department of Natural Resources (DNR) - The Missouri Department of Natural Resources is a state agency that monitors natural settings, evaluating soil and water quality and the effect of pollution. They enforce regulations concerning pollution. This department may provide information about designing manure management systems.

Environmental Protection Agency (EPA) - The EPA is a federal agency responsible for the enforcement of federal environmental policies and laws. The agency provides information on the laws and rules governing the use of manure. This information would be especially useful when designing the system.

Planning a Manure Management System

Farmstead planners should carefully research the different types of manure management systems available and obtain professional help as needed. This aspect of the farm plan should not be taken lightly; whatever system is chosen, it must work properly for the enterprise to be successful. The regulatory agencies listed above will be of some assistance in choosing a manure management system. The following sources of information may be able to supply specific designs and referrals to other sources. These sources can be located through phone directories, library reference services, or Web searches.

- University Extension offices

- Natural Resource Conservation Service (NRCS) offices
- Associations for a particular species of livestock (such as the National Pork Producers Council and National Cattlemen's Beef Association)
- Private agricultural engineering firms
- For producers with contracts with large corporations, engineers who assist with design that are hired by the corporation

Summary

The main goal of manure handling systems is to prevent the pollution of surface and ground water. Depending on the type of livestock enterprise, manure management can be very involved. Planning for an appropriate system may require research involving government agencies, livestock associations, and other sources of information.

Credits

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Lesson 1: Construction Safety

This unit presents an exploration of building construction. Bureau of Labor statistics for 1997 show that the construction and agriculture (including forestry and fishing) industry divisions both have high fatality rates relative to the level of employment in those industries. Because these industries have such high rates of injury and illness, the first lesson of this unit focuses on safety. Being aware of and following good safety practices is absolutely imperative to protect everyone involved in the construction of a structure. It is important to stay alert, pay attention, and think ahead to avoid injury.

A few general considerations may help prevent or reduce the seriousness of injuries. Suitable protective equipment and clothing should be used as necessary. Long pants, long sleeves, and thick-soled shoes or work boots are highly recommended. For some jobs, a hard hat, work gloves, eye protection such as goggles or safety glasses, and hearing protection like ear plugs may also be required. Workers should try to avoid hazardous jobs while alone or isolated from others in case an injury occurs that requires assistance. Keeping a first aid kit at the site may also help in dealing with any injuries that do occur.

Construction Careers

Building construction
Remodeling and renovation
Estimator
Bricklayer
Heavy equipment operator
Terrazzo builder
Building supply retailer

Specialization in:
- Foundation work
- Framing
- Drywalling
- Insulating
- Roofing
- Siding

Heights and Safety

Working with heights is often unavoidable in construction. Falls from heights contribute significantly to the number of injuries and fatalities that occur in construction. While heights do present some special safety concerns, the risks can be minimized by observing the following safety tips.

- Ladders or any other equipment, such as scaffolds or lifts, must be well maintained and in good working order. Never use faulty equipment.
- The base of a ladder or the legs of a scaffold must be properly seated. They must be evenly set on a solid, non-slippery surface.
- Use any applicable safety equipment, such as safety belts and boots with non-skid soles.
- Use extra caution when carrying materials. Keep loads small enough to be manageable.
- Be aware that roofs can be slick, especially early in the mornings when dew may be present. Move slowly and carefully.
- Do not attempt to work at heights if experiencing any dizziness or disorientation.

Safety with Construction Equipment and Tools

Construction projects may involve the use of a wide array of equipment and tools. Some of them, such as a hammer, are very simple to use, while others, such as propane torches, require more knowledge to operate correctly. However, most equipment and tools can cause injuries if they are handled carelessly. To use construction equipment and tools effectively and efficiently, remember the following tips.

- Keep tools well maintained and in proper working order.
- Use tools for their intended purpose. Most tools are designed for specific purposes, and their use for other jobs is frequently unsatisfactory or dangerous.
- Follow the manufacturer's instructions for the use of equipment and tools. Also, take heed of any safety recommendations.
- Fatigue will dull the senses and can contribute to carelessness, which can be hazardous when working with equipment and tools. Take breaks as needed. Construction work requires your full attention at all times.

Safety and Structural Elements

Structural elements are all the materials that go into a construction project. They will vary with each project. Some examples would be lumber, steel, concrete, and plumbing and electrical supplies. To handle these materials safely, remember the following guidelines.

- Unloading materials at a work site can present a variety of hazards. Materials may be large and heavy. Care should be taken when loading and unloading. Avoid standing where materials (or the equipment handling them) could be a hazard in the event of a mishap. Always try to find a position that would be safe from an unexpected spill--at the end of the material if it is stacked very high or, with concrete being delivered, facing the truck while it unloads.
- Care and good technique are necessary when lifting construction materials. They should be moved in some other way if possible, such as pushing, rolling, or sliding. If materials must be lifted, the best way to do so is to bend at the knees, keeping the back straight, and lift the object by straightening the legs. The process should be reversed when setting materials down. To turn, the feet should be moved to a new position; twisting at the waist should be avoided to prevent back injuries.
- Some materials, such as concrete, may be caustic and should be handled wearing protective clothing and boots.
- Electrical hook-ups are often necessary at construction sites. They should only be assembled by someone who is very knowledgeable and qualified to establish such service. Sufficient grounding and devices that provide protection from current (such as circuit breakers) must be in place.
- Materials and waste materials should be kept organized and out of the way while working. Leaving materials in an area of activity creates a situation where workers can trip.

Summary

While following the tips on working with heights, equipment and tools, and structural elements given in this lesson will improve safety at a construction work site, the most important step in preventing injury may be paying close attention to what is happening. An awareness of what is going on will allow a worker to avoid hazards and thus reduce injuries on the site.

Credits

National Institute for Occupational Safety and Health (NIOSH). "The National Ag Safety Database (NASD)." http://www.cdc.gov/niosh/nasd/nasdhome.html (5 Oct. 1998).

Bureau of Labor Statistics. "National Census of Fatal Occupational Injuries, 1997." http://stats.bls.gov/special.requests/ocwc/oshwc/cfoi/cfnr0004.txt (13 Oct. 1998).

Lesson 2: Building Designs

Agricultural structures use many different types of styles and designs because of the vast diversity of agricultural enterprises. This lesson describes some common building designs and factors that should be considered when designing and constructing agricultural structures.

Designs for Agricultural Structures

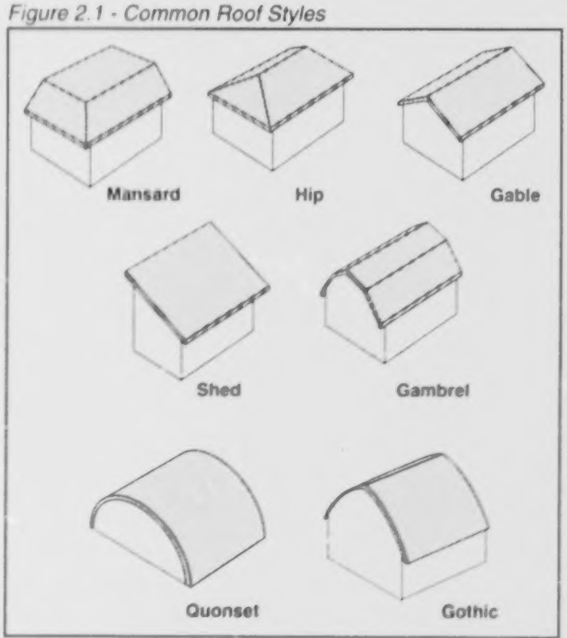
Although any conceivable design or combination of designs may be used for agricultural structures, certain basic shapes and roof styles are most commonly used. Structures are generally square, rectangular, round, or oval in shape; they may also be some combination of these shapes. Roof styles also are a significant factor in design; many structures are commonly referred to by the roof style used. Seven roof styles--gable, hip, mansard, gambrel, shed, Quonset, and Gothic/arched--meet most agricultural needs. A gable roof has two sloping sides that meet at the peak of the building, while a hip roof slopes on all four sides from the peak. A mansard roof is similar to a hip roof in that it slopes on all four sides, but the upper part of the roof is flat. In the gambrel roof style, the sides slope slightly from the ridge to about halfway down the roof and then slope more steeply. A shed roof is sloping, with no ridge. A Quonset building is basically a half circle, with a rounded roof and walls. A Gothic or arched roof has two continuous curves that come to a peak to form the roof. Figure 2.1 shows these different styles.

Methods of construction vary with the types of materials selected for the structure. Several common methods of construction are used when building agricultural structures. Agricultural structures may also make use of aspects of all four of these basic methods of construction.

Wood frame - Wood frame construction involves the use of weight-bearing upright wooden members for the walls of a building. An example of this type of construction is a shed with stud walls.

Pole - In pole buildings, often called post frame buildings, large wooden timbers are placed in the ground and serve as the weight-bearing skeleton of the building. This type of design is often used for hay barns and shelters for farm machinery.

Figure 2.1 - Common Roof Styles



Metal - Metal construction refers to any structure where metal is used as a primary component of the building. Because of its strength and stability, metal is sometimes used in place of wood in pole-type construction. Structures are built by welding and bolting the materials together. This type of construction is often used for machine storage sheds.

Masonry - In masonry construction, concrete or masonry blocks are the primary building material. Buildings are constructed by pouring concrete in forms or laying blocks. The use of masonry is very common for some types of agricultural structures, such as manure handling, because it produces a durable surface that can be cleaned and disinfected easily.

Advantages and Disadvantages of Different Designs

The advantages or disadvantages of each type of structure must be evaluated while keeping in mind its intended uses, the builder's options, and site restrictions. One type of structure cannot successfully meet the needs of every possible situation. To evaluate the suitability of a structure for a project, the following questions should be considered.

- Will the structure serve its intended purpose? Is it efficient?
- Are the construction and operating costs reasonable? Will using a particular design or material save money?
- Can the building be heated or cooled if required?
- Are the building materials durable enough to last for the life of the structure?
- Can the building be partitioned off or expanded if necessary?

Wood frame structures are often more economical than the other types. They are usually relatively easy to partition or expand. However, wood frame buildings will likely require more maintenance and may not be durable under conditions of abusive use. They also pose an inherent fire hazard because of the use of wood in their construction.

Pole buildings can be constructed rapidly and economically. With good maintenance and repair, the buildings can have a long life span. Partitioning or expansion of the existing structure is usually easily accomplished. However, they may provide inferior weather protection, because they often do not have solid sides. They generally cannot be heated or cooled without modifications being made to the structure.

Metal buildings often are serviceable for a long time; they are also fire resistant. Disadvantages of metal structures are that they may be expensive and require special equipment and considerable skill to build. They also may be short-lived around manure.

Since masonry can be cleaned and disinfected easily, as discussed above, it is often the best choice for structures that require frequent cleaning with water. Masonry is also fire resistant. The life span of masonry or concrete structures is generally very long, and they require minimal maintenance. Building with masonry may be more costly, however. The use of concrete may also require extensive excavation, depending on the topography. While masonry structures may be expanded or partitioned, tearing down masonry for expansion is a labor intensive process.

Factors to Consider For Design or Construction

A structure's intended uses must be specifically identified before the style of the design or the materials used are determined. The activities that will take place in a building may determine the best type of design. For example, a pole building will generally not be appropriate for swine nurseries.

A second factor to consider is whether the cost of construction is reasonable enough to allow successful operation or use. The building's use must justify its construction cost. An example would be to borrow money to erect a hay storage facility at a cost of $100,000 and only produce enough hay to average $5,000 per year in returns, which would likely not pay the interest on the loan or produce any profit.

The builder must determine whether the proposed structure is appropriate for local environmental conditions. Different designs and building materials affect a building's ability to function in its environment. Before making any decisions about design and the materials used, determining the amount of weather protection needed is important. The steepness of the roof will affect the structure's ability to deflect rain, snow, or ice. The type of wall construction and the materials used will determine how much weather protection is provided by the walls. Foundation designs vary from bare earth to raised floors of metal, concrete, or wood products that meet the requirements of the environment and the structure's intended use. The tremendous diversity of building materials, designs, and environmental conditions makes it impossible to give specific recommendations. However, tables and charts that detail specifics for weather and load, which is the weight carried by a part of a structure, recommendations are available from sources such as University Extension services, libraries, and manufacturers of building materials.

Since some structures may be unacceptable according to the regulations for a particular area, codes and regulations for construction must be consulted when choosing a design for a structure. A county planning and zoning office can supply specific information about required wiring, plumbing, structural specifications, and permits. They may also suggest additional sources of information.

Finally, the efficient use of materials must be considered. The efficient use of materials is often a compromise because using them efficiently to provide the most space does not always yield the most functional design. Even though a square, rectangle, and circle have the same perimeter, they do not contain the same amount of interior space. Rectangular buildings are the most inefficient use of materials; however, they are frequently the most functional in use because the flow of activities typically follows a horizontal line. Square designs are more efficient and are suitable for many applications, although they are not as popular in the construction industry. Circles are very efficient in the use of materials but are usually not efficient in use or ease of construction.

Summary

When choosing a design for an agricultural structure, the intended use of the structure is perhaps the most significant factor, although other factors that may affect the design and its advantages and disadvantages must also be considered. Information is readily available to provide help in identifying options. Anyone considering constructing a large structure should seek appropriate help, which is often very inexpensive or free from government sources. Professionally prepared plans generally are designed to take many factors into account and may be an excellent choice for use in constructing a structure.

Credits

Burch, Monte. *How to Build Small Barns and Outbuildings*. Pownal, Vt.: Garden Way Publishing, 1992.

Huth, Mark W. *Construction Technology*. Albany, N.Y.: Delmar Publishers, 1989.

Lindley, James A., and James H. Whitaker. *Agricultural Buildings and Structures*. Rev. ed. St. Joseph, Mich.: American Society of Agricultural Engineers, 1996.

Lesson 3: Building Materials

Many options are available for materials for use in construction, and structures may contain a variety of materials. Evaluating factors such as the project's purpose and the availability and cost of materials will be necessary to select the appropriate materials.

Different Types of Building Materials

Agricultural structures are constructed from many types of materials. Among the materials used are wood, metal, concrete, clay bricks and tiles, vinyls, plastics, glass, and fiberglass.

Wood products come in a variety of forms, including boards and plywood. They have many uses, including structural members for building the frames of structures, siding, and floors. Because wood is so common, it is the focus of this unit.

Metal products, such as steel and aluminum, are widely used in agricultural projects, often for structural members, roofing, or siding. Specific uses include support beams, roofing, sealing for the edge of a roof, trim on the corners of buildings, and many others. Metal materials generally are sold to an exact size, since cutting is more difficult than it is with lumber. Metal is also more difficult to patch or repair on a building.

Concrete products are most often found in medium-sized and large structures, usually in the foundation and often in various other parts of the structure. Concrete may also be used for sidewalks, driveways, and other paved areas. Concrete products used in construction include cinder blocks and mixed concrete. Concrete products are generally sold to meet exact specifications.

Clay bricks and tiles are available but are generally used in small quantities for agricultural structures. Bricks are sometimes used to build houses. They are generally used for decorative purposes. Other common uses of clay bricks or tiles would be for a fireplace or for walkways. Clay bricks and tiles can be purchased in many different shapes and colors. They are difficult to cut or repair.

Vinyls, plastics, glass, and fiberglass have more specialized uses. Vinyl is commonly used for siding on houses. Plastics are used for skylights to allow sun into a building, as well as siding for greenhouses. Glass is used for windows, and fiberglass is used for skylights, greenhouse covers, and for livestock equipment like water tubs.

Grades and Types of Dimension Lumber

Dimension lumber refers to wooden building material sawn in lengths, usually starting at eight feet and increasing in increments of two feet. It is uniform in thickness and width. Dimension lumber makes up the framework of wood-frame structures.

As dimension lumber is processed, it decreases in size. Freshly cut lumber will shrink considerably as it dries, up to 1/16 of an inch across its shortest dimension. Surfacing and milling of the lumber, which is standard in the industry, will also claim some of the material. The measurements of the lumber before any of this processing are the nominal dimensions. Afterwards, the material is referred to as dressed. This loss of material usually amounts to 1/4 of an inch off each side of the width and height. Thus, an eight-foot 2" X 4" is actually 8 feet long, 1½ inches high, and 3½ inches wide.

Dimension lumber is measured in board feet. A board foot is equal to 144 square inches. This measurement can be calculated by multiplying a board's nominal length (in inches), width, and height and dividing this number by 144. An eight-foot 2" × 4" is 5.33 board feet (2 in. × 4 in. × 96 in. = 768 in^3.; 768 in^3. ÷ 144 in^3. = 5.33 board feet.)

Materials used for dimension lumber are classified as softwood or hardwood. This designation is a source of confusion in that it does not refer to the actual hardness of the wood but to the type of tree. Softwood refers to lumber from evergreen trees, such as pine or spruce trees. Hardwood is lumber from deciduous trees, or trees that lose their leaves, like oaks.

Other possible classifications of lumber are green or kiln dried. Green lumber is lumber with a high moisture content. This type of lumber is sometimes used in agricultural structures to save on material costs. However, it is prone to warping and twisting as it dries, which makes it undesirable for most projects. With controlled drying, much of this distortion can be avoided, and the material is much more stable. Wood is most commonly dried in a kiln, a sort of oven in which the lumber is heated, often to over 200 degrees Fahrenheit, to reduce moisture to a desired point. For example, wood used for framing is dried to about a 15 percent moisture content. Electronic moisture meters are used to determine the exact moisture content of the dried lumber.

Lumber is sometimes chemically treated for preservation. Treated lumber is more resistant to moisture and will last longer in wet climates. Generally, treated lumber will last at least twice as long as untreated lumber. Chemicals can make wood very rot resistant but require care when used, because they may be toxic. Manufacturer's recommendations should be followed carefully.

After lumber is sawn and dried to an acceptable level, it is assigned a structural grade. In the United States, the American Lumber Standards Committee sets certain standards for grading lumber. Their guidelines are generally applied, and often expanded or detailed, by regional associations such as the Western Wood Products Association or Southern Forest Products Association. These associations may set grading guidelines for the types of lumber produced in their areas.

The number of grades available is variable. Depending on the number and severity of defects, lumber is generally graded 1, 2, or 3 (1 being the highest number grade), possibly with an additional premium or select grade. Each piece of lumber graded is evaluated for the following defects.

- Knots from embedded branches or limbs
- Splits or checks, which are separations of the wood fibers along the grain or across the annular growth rings
- Shakes, or separations between the annular growth rings
- Pitch pockets, which are cavities that have or had pitch in them
- Honeycombing, or separation of the wood fibers inside of a tree
- Wane, which is bark or the absence of wood along the edge of a board
- Blue stain, discoloration caused by a mold-like fungus
- Decay caused by fungi that rots the wood
- Holes from any source
- Warp, usually resulting in bows, cups, crooks, or twists in the lumber

Sometimes other terminology is used to refer to different grades of lumber. For example, "economy" generally is equivalent to grade three. Some areas may have further designations involving letters or terms such as (S) or Select, (B) or Better, (C) or Common, Choice, or Supreme. These letters may or may not correspond to a number system. If the grade of lumber is unclear, explanations can be obtained from the retailer handling the material.

In addition to a structural grade, dimensional lumber that has been chemically treated is labeled as treated lumber. Treated dimensional lumber for outside use has a tag attached to each piece of material with information about the chemicals used.

One thing to keep in mind when selecting graded lumber is its use. For agricultural structures, near perfect cosmetic appearance usually is not necessary. A considerable amount of money can be saved by selecting suitable material of a lower grade. When in doubt, the structural integrity of a specific grade of lumber can be confirmed by a reputable retailer.

Grades and Types of Sheathing Material

Sheathing materials are generally wood or wood product panels manufactured in one of several ways. The panels are most commonly four feet by eight feet in size, with a thickness of ¼ to 1 7/16 inches. The measurements of sheathing material are actual and correct.

The following types of sheathing material are the most common. Plywood is made of thin sheets of wood laminated to a desired thickness. Composite plywood has a wood veneer cover laminated to some form of wood core. Nonveneered panels, such as oriented strand board (OSB), particle board, and wafer board, are all made from wood flakes, chips, or fibers that are combined with suitable resins and glues and shaped into panels. These nonveneered products are not, however, interchangeable with one another; each has advantages or disadvantages related to strength, cost, and weather resistance. Plywood grading systems vary somewhat depending on the type of material. Softwood plywood grades are assigned by associations such as the APA to sheathing materials manufactured to meet their specifications. The material is rated as to its suitability for interior or exterior use;

Figure 3.1 - Veneer Grades

VENEER GRADES

A	Smooth, paintable. Not more than 18 neatly made repairs, boat, sled, or router type, and parallel to grain, permitted. Wood or synthetic repairs permitted. May be used for natural finish in less demanding applications.
B	Solid surface. Shims, sled or router repairs, and tight knots to 1 inch across grain permitted. Wood or synthetic repairs permitted. Some minor splits permitted.
C Plugged	Improved C veneer with splits limited to 1/8 inch width and knotholes or other open defects limited to 1/4 x 1/2 inch. Wood or synthetic repairs permitted. Admits some broken grain.
C	Tight knots to 1-1/2 inch. Knotholes to 1 inch across grain and some to 1-1/2 inch if total width of knots and knotholes is within specified limits. Synthetic or wood repairs. Discoloration and sanding defects that do not impair strength permitted. Limited splits allowed. Stitching permitted.
D	Knots and knotholes to 2-1/2- inch width across grain and 1/2 inch larger within specified limits. Limited splits are permitted. Stitching permitted. Limited to Exposure 1 or Interior panels.

generally, a rating of 1 indicates that the plywood is for exterior use, while a rating of 2 is for interior use. Plywood with a rating of "Exposure 1" can withstand moisture but should be used indoors, while "Exposure 2" indicates plywood that should only be used indoors. The quality of the veneer used on the face and back is rated with a letter system shown in Figure 3.1.

A plywood grade stamp from the APA, which supplies a variety of information, appears in Figure 3.2. A span rating may be shown as two numbers separated by a slash. The first number is the maximum span in inches between supporting boards that should be used with this material for roof decking; the second number is the recommended span for floor decking. Other information that appears in the stamp includes the panel grade, exposure durability, and thickness.

The Hardwood Plywood Institute also has a number system used for grading. A rating of 1 or 2 is given to material with a good face and back with careful grain matching. A rating of 3 is assigned to plywood that is structurally sound but has obvious defects and patching. Softwood or hardwood plywood may also be designated G1S, meaning "good one side," or G2S for "good two sides."

Nonveneered panels are manufactured by many manufacturers and from a variety of materials. This industry is very innovative, and new techniques and forms are being developed regularly. Information on grades for these sheathing materials can be obtained from the manufacturer or retailer. They may use a system of grading very similar to that for plywood, but if in doubt, ask.

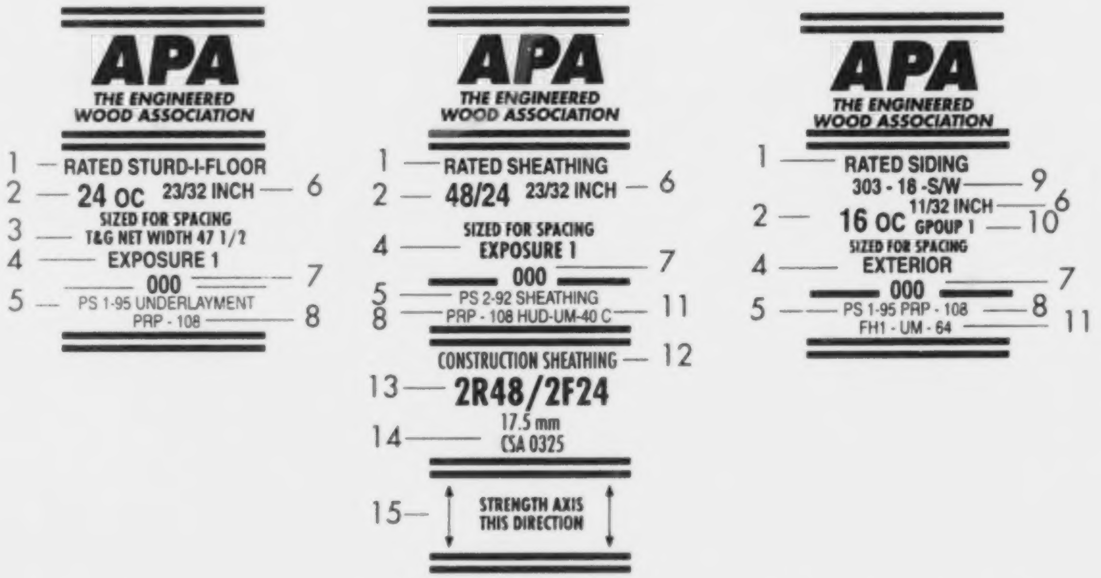
Summary

A variety of materials are used in structures, but the majority of agricultural structures contain some wood products. Wood products come in a wide variety of dimensions and grades. The actual grades assigned to wood may be indicated by numbers, letters, or names. The system of grading can be confusing: asking the retailer for explanations may be the easiest way to determine the grade suitable for a project.

Credits

Huth, Mark W. *Construction Technology*. 2nd ed. Albany, N.Y.: Delmar Publishers, Inc., 1989.

Lindley, James A., and James H. Whitaker. *Agricultural Buildings and Structures*. Rev. ed. St. Joseph, Mich.: American Society of Agricultural Engineers, 1996.


APA
THE ENGINEERED WOOD ASSOCIATION
RATED STURD-I-FLOOR
24 OC 23/32 INCH
SIZED FOR SPACING
T&G NET WIDTH 47 1/2
EXPOSURE 1
000
PS 1-95 UNDERLAYMENT
PRP - 108
APA
THE ENGINEERED WOOD ASSOCIATION
RATED SHEATHING
48/24 23/32 INCH
SIZED FOR SPACING
EXPOSURE 1
000
PS 2-92 SHEATHING
PRP - 108 HUD-UM-40 C
CONSTRUCTION SHEATHING
2R48/2F24
17.5 mm
CSA 0325
STRENGTH AXIS THIS DIRECTION
APA
THE ENGINEERED WOOD ASSOCIATION
RATED SIDING
303 - 18 -S/W
16 OC 11/32 INCH
GROUP 1
SIZED FOR SPACING
EXTERIOR
000
PS 1-95 PRP - 108
FH1 - UM - 64
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

1 Panel grade
2 Span Rating
3 Tongue-and-groove
4 Exposure durability classification
5 Product Standard
6 Thickness
7 Mill number
8 APA's performance rated panel standard
9 Siding face grade
10 Species group number
11 HUD/FHA recognition
12 Panel grade, Canadian standard
13 Panel mark - Rating and end-use designation, Canadian standard
14 Canadian performance rated panel standard
15 Panel face orientation indicator

Figure 3.2 - Typical APA Plywood Grade-Trademark

Lesson 4: Fasteners and Fastening Systems

Many forms of materials are used in construction. They require a variety of fasteners and fastening systems. This lesson introduces some common fasteners and systems and gives some examples of where each could be used.

Groups and Uses of Fasteners

Fasteners can roughly be grouped into four categories: nails, screws, adhesives, and anchors. Nails are the most common and are generally used for attaching wood pieces together. Screws are also used for attaching wood pieces but may be used to attach metals as well. Adhesives are commonly used in agricultural construction and can bond many types of materials. For example, many trusses and roof support beams are glued together, dramatically increasing the strength of the roof, sometimes as much as 60 percent. Construction anchors are a large assortment of devices used to attach walls to foundations. Framing anchors are used to attach framing members together.

Selecting Nails

The most commonly used fasteners in building construction are nails. Factors that affect the selection of nails for construction are the uses of the nails, the nail length required, and exposure to weathering.

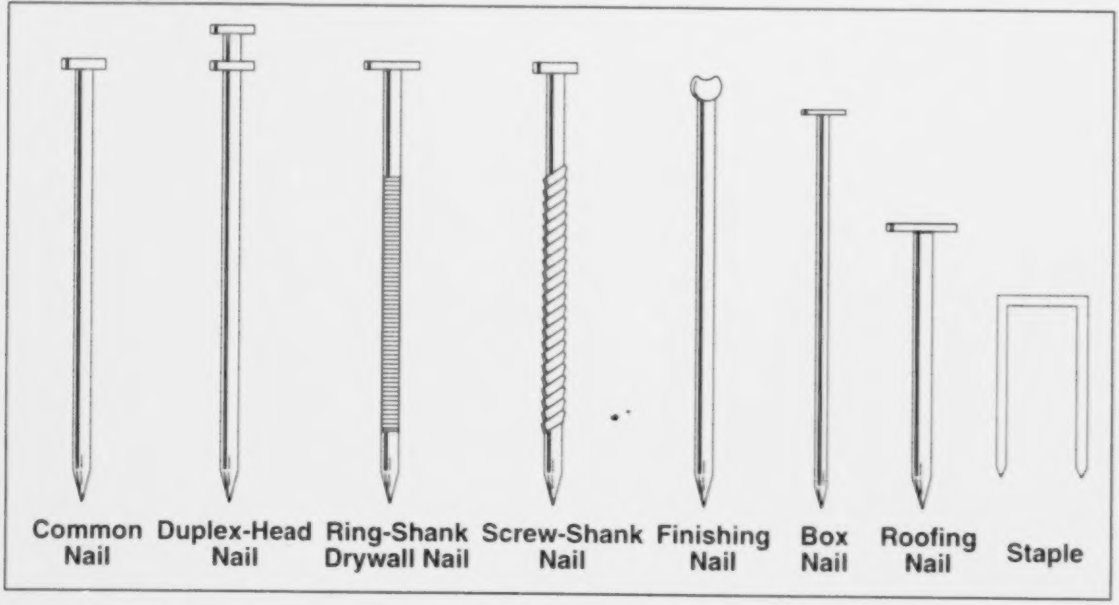
Nails come in many different styles, as shown in Figure 4.1. For example, common nails are the most commonly used type of nail, as their name implies. They are general purpose nails used anywhere a special purpose nail is not needed.

Box nails have a thinner head and shank, or body, than common nails. Being thinner makes them less likely to split the wood. The thinner heads are also easier to cover with paint. Box nails were originally used to make small boxes to ship food and other items. Now they are often used in finish cabinet work to avoid splitting. Box nails are often chemically coated to resist rusting, which can discolor paint or wood.

Finish nails have very small heads and smaller shanks than common nails. The small heads make them less noticeable, so they are useful for finishing. The nail may be countersunk, with the head of the nail set below the surface of the wood; the head is then concealed with wood putty, leaving a very nice finish for exposed, decorative wood. However, because the head is so small, the nails have less holding ability.

Duplex-head nails serve special purposes. Once driven into the wood, they still have a head

Figure 4.1 - Types of Nails



extending above the surface, which allows them to be removed easily with the claws of a hammer. Duplex-head nails are commonly used when nailing together concrete forms, so they can be taken apart and removed more easily. The extra head also provides a good place to tie strings for marking.

Roofing nails are used for nailing shingles in place. They have very wide, flat heads to hold shingles down. Often these nails are made of rust-resistant material, such as aluminum.

Ring-shank nails have small circles or rings around the shank. These rings make the nail hold tighter; they are also more difficult to remove. The heads of ring-shank nails are often cupped to increase their holding ability. Ring-shank nails are used for applications where the nail will never be removed and the material needs to be held tightly. For example, ring-shank nails are often used for nailing the treads on a set of stairs. Using ring-shank nails will decrease the loosening of the boards later and help keep the steps from becoming shaky.

Screw-shank nails come in a variety of materials, like steel, copper, and aluminum, for different applications. These nails have a twisted shaft, which causes the nail to turn as it is driven into the material. Because of the twisting, the nail is difficult to remove. Screw-shank nails are used where good holding ability is needed, such as on decks. Some of these nails are very heavy duty and can be driven into concrete.

Staples are U-shaped fastening devices; its ends are driven into a surface to hold material in place. They are commonly listed and sold with nails. Staples are frequently used for attaching wire but are also very commonly used to attach plastics or vinyl.

Other specialized nails have a variety of uses. Some special nails attach metal roofing. These nails have a rubber washer system next to the head to help seal out moisture. Cement-coated nails are coated with an adhesive to increase their holding ability. Other specialized nails are those for use with power or air nailers. These tools drive nails with air, electric current, or gun powder. The nails used in nailers are sold in strips or coils, with the nails attached to each other to make loading the gun easier. The nails are separated as the gun drives the nail into the material. A complete array of nail and staple sizes for nearly any application are available for use with these tools.

The many uses of nails require that they come in a variety of sizes. Figure 4.2 illustrates the most common sizes, although nails come in other sizes as well, such as spikes of eight or more inches in length. Nail lengths are designated by the term "penny" and the letter "d," which was an abbreviation for penny in England. Penny comes from the early days of nail making and indicated that 100 nails of that length could be purchased for that number of pennies. This measurement was adopted world-wide as a standard for nails. Penny does not correspond to the shank diameter; a 6d common nail, 6d finish nail, and 6d box nail would all be two inches in length but have different diameters. The diameter varies by the manufacturer and material. Typically, the nail length selected for an application should be long enough to pass entirely through one board and at least half the thickness of the board to which it will be attached.

Another factor that affects the selection of nails is their exposure to weathering. If the nails will be exposed, the builder should choose nails that will resist corrosion or staining, such as zinc or aluminum nails.

Screws

Screws are used frequently in building construction because they have a higher holding capacity than nails. As shown in Figure 4.3, several styles of screw heads are used. Round or oval heads are strong in design, but the head remains above the surface. Flat head screws are flush with the surface and are easier to hide with paint. With pan head screws, a small head remains above the surface after insertion. Pan head screws are commonly used when the head of the screw will also be decorative, as for some cabinets.

Screws most commonly come with one of two types of slots in their head, straight-slot or Phillips (Figure 4.4). Either is available for most common screws, and both work well. Often screws with Phillips heads are more popular because they lend themselves to being driven using electric screwdrivers or drills with Phillips head bits. Other styles of slots are available, such as square, Allen, or star configurations, but they are usually designed to work with a specific tool.

Figure 4.2 - Common Nail Sizes

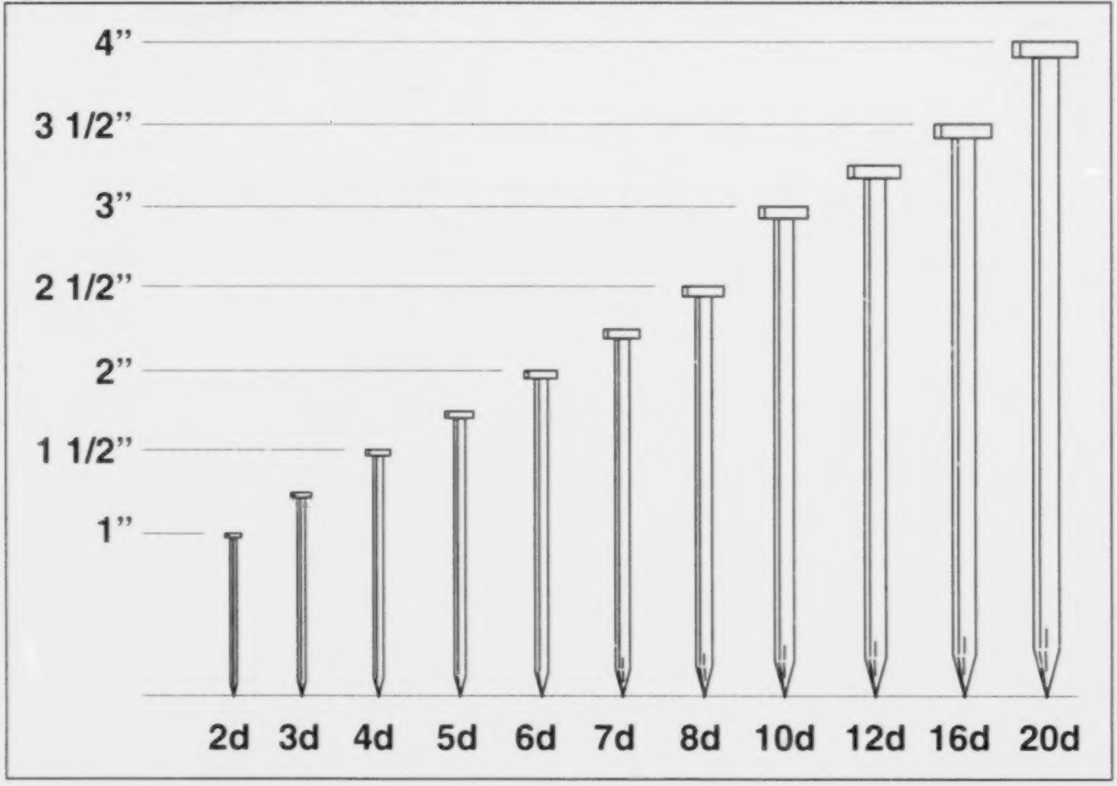


Figure 4.3 - Screw Head Styles

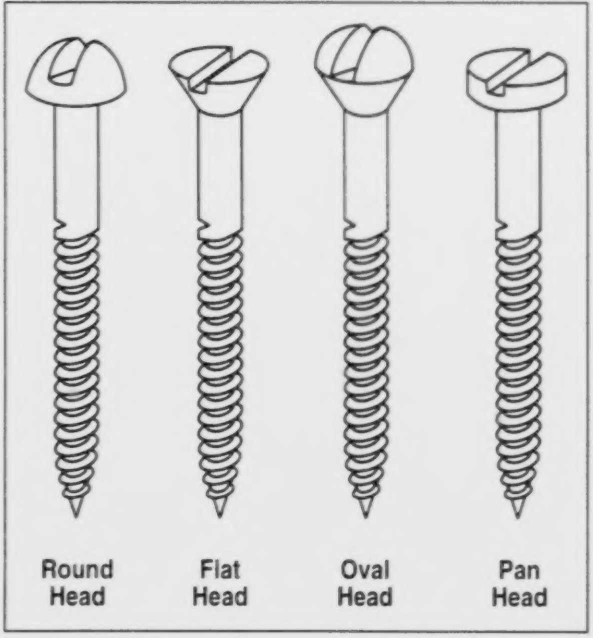
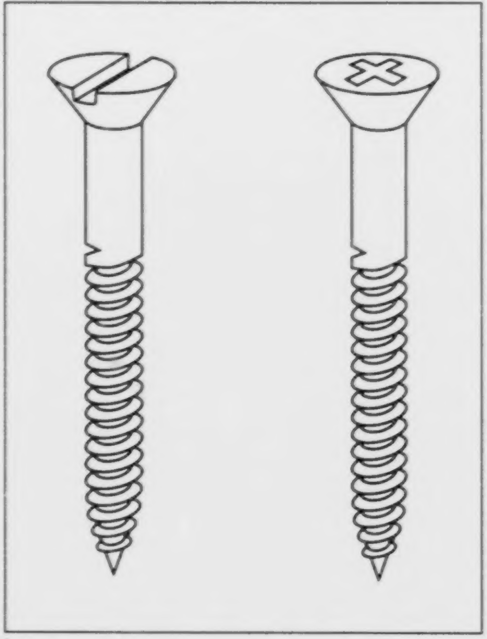

Round Head
Flat Head
Oval Head
Pan Head

Figure 4.4 - Straight-Slot and Phillips Screws



Wood screws are used to attach wood. They are often used in combination with adhesives, which can produce a bond much stronger than the screw itself. Wood screws may be made of several materials: brass, which is rust resistant for outside use; steel, which is stronger and less expensive than brass; or aluminum. Galvanized screws are also available for outdoor applications. Screws are sold in various lengths, usually ¼ inch to 4 inches, and by gauge, which indicates the screw's diameter. The larger the gauge, the larger the diameter; common gauges range from zero to eighteen.

Self-tapping metal screws are used with sheet metal or metal siding in building construction. These screws do not require a guide hole and will enter into the material more easily than other screws. They are usually mechanically placed and have Phillips-type heads or some type of star configuration. They are similar in appearance to wood screws and vary according to manufacturer or designated use.

Drywall screws are used to secure drywall to walls and ceilings. They have a flat head that countersinks into the surface of the drywall. They may be placed using a screw gun or an electric drill with a special drywall bit attachment. Nails may also be used with drywall, but screws provide better holding power.

Adhesives

Adhesives are commonly used in building construction and are gaining in popularity. Their uses are increasing due to improvements in manufacturing in recent years. Two important terms need to be defined concerning adhesives. Adhesion refers to the ability of materials to stick to each other, while cohesion refers to the attraction between the molecules of a material, like the particles of wood. An adhesive with good adhesion but poor cohesion will stick to a material and then be easily pulled off.

Wood glues are used for joining woods. In the past, wood glues were made from animal products. These glues have now largely been replaced by glues based on some form of plastic. Polyvinyl, or white wood glue, is very good for most interior or furniture woodwork. Urea formaldehyde, which is a plastic resin glue, is strong, water resistant, and adheres well to wood. It can be used to make repairs in wood splits or to reinforce joints in a defective truss. Waterproof resorcinol resins are used on wood where water exposure is likely.

Epoxies are modern and extremely strong bonding materials. They are now being used in the assembly of automobiles, for bridge repair, and on structural steel joints. Epoxies are commonly used on fiberglass and plastics. If an exceptionally strong bond is required, consult a retailer about an epoxy product.

Mastics use cohesion to attach materials with large surface areas, such as floor coverings. They usually have a synthetic rubber base. Most mastics are water resistant. Contact cements, which are a type of mastic, are commonly used to attach laminates to counter tops or for vinyl floor coverings.

Adhesive applications or alternatives exist for nearly any fastening situation. A combination of adhesives and other fasteners is also very common and can create excellent bonds. Often cost and time are the limiting factors when deciding if adhesives are the best option.

Adhesives should always be used with caution. Many of them are highly toxic or produce toxic fumes, may be absorbed though the skin, and can be very flammable. Read and follow all manufacturer's recommendations when using these products.

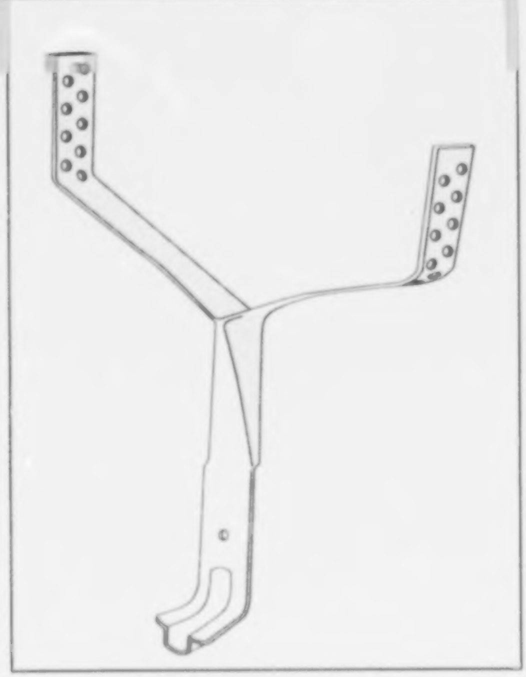
Construction Anchors

Construction anchors are generally used to attach walls to foundations. Anchor systems are often used to help protect the structure against damage from high winds by adding more strength and stability. Factors such as wind shear, weight, soil type, and foundation conditions will affect the type of anchor system chosen.

One type of construction anchor is an anchor bolt. Bolts are threaded pieces of metal used with nuts and usually either washers or metal plates, both of which distribute the bolt's holding strength over a larger area. Large bolts are set into the foundation to serve as anchors. They secure the bottom of the wall to the concrete.

Various types of anchor systems can also be used. One type of anchor involves metal straps set in concrete and then attached to the wooden

Figure 4.5 - Sample Construction Anchor



member in the wall; an example is shown in Figure 4.5. Other designs involve anchors screwed into the ground with metal cables attaching them to the structure.

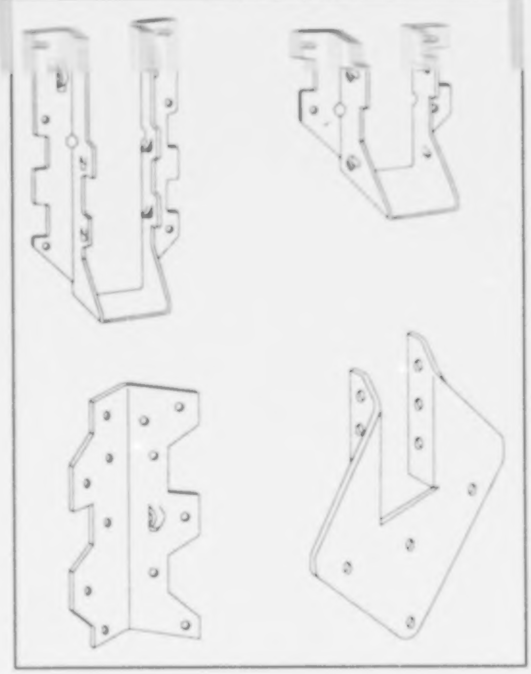
Framing Anchors

Framing anchors differ from construction anchors in that they attach framing pieces together. Usually, they are used for activities like setting joists in place, attaching the roof to the walls, attaching walls to each other, and joining the parts of a truss together. The anchors therefore have specific shapes for a particular purpose. Figure 4.6 shows some different types of framing anchors.

Summary

Nails, screws, adhesives, and anchors are the most commonly used fastener groups. Nails are the most common and come in sizes and styles appropriate for nearly any situation. Screws also come in a vast assortment of sizes to meet the many demands placed on them. Adhesives are becoming more cost effective and useful for many types of materials and may replace many of the other fasteners in the future. Anchors are used to attach walls to foundations and join framing members.

Figure 4.6 - Sample Framing Anchors



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Lesson 5: Floors and Subfloors

The needs of the structure are the primary factor in determining what type of floor will be best for that structure. This lesson explores some of the basics of constructing floors. However, concrete, one of the most popular types of floors for agricultural structures, is not covered here.

Floor Framing Members

Floor framing is the structural portion of the building that rests on the concrete foundation and attaches the building to it. The framing forms the base of the structure. Floors consist of a number of components. Figure 5.1 shows some of these parts.

Crawl space - The crawl space is found between the ground and the first floor in structures without a basement.

Sill plate - This term refers to a piece of material, usually made of wood or metal, that is attached to the foundation. A wood sill plate is usually a 2-inch thick board that is 4, 6, or 8 inches wide. The sill plate is the place where the building frame attaches to the foundation. It supports the floor joists.

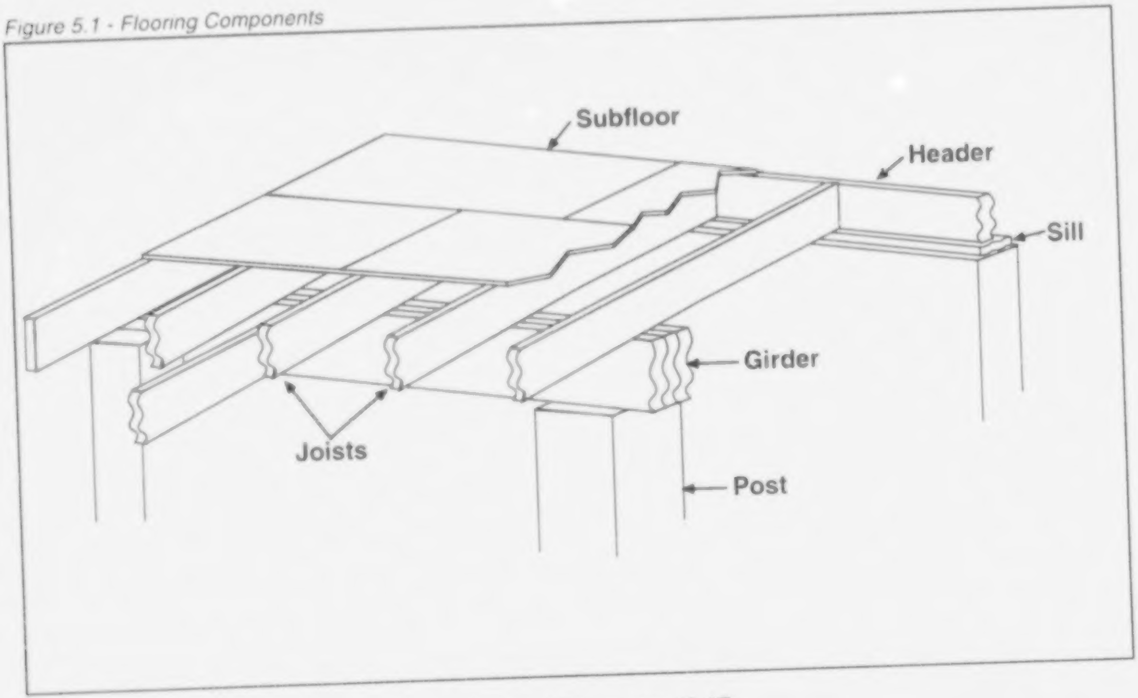
Girder or beam - If floors are too wide to be spanned across their full width by one piece of material, girders or beams are used to support the structure. They may be large pieces of dimensional wood, a combination of dimensional wood and plywood, metal, or some fabricated combination of metal and wood. Girders support the weight of the structure at certain points along their length. These girders are supported at intervals by posts. Girders and their supporting posts are generally used for structures with floor spans of more than twelve feet. The girders are attached together using metal plates and bolts.

Post - The posts that support the girders may be made of wood, metal, or concrete. If the supports are made of concrete, they are referred to as concrete piers, while metal posts are often pipes, called pipe columns.

Header joist - The header joist attaches to the sill to form a box sill. It also attaches to the ends of the joists.

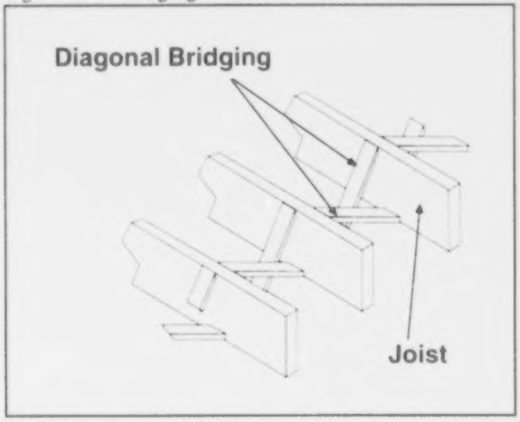
Joist - A joist is the wood or metal member that rests on the sill and supports the first layer of flooring and the weight of the structure. Floor joists are typically made of 2" × 8", 2" × 10", or 2" × 12" boards.

Figure 5.1 - Flooring Components



Bridging – Bridging are small wooden or steel pieces fitted in pairs between the joists. They are crossed to reduce movement of the joist and help distribute weight. Figure 5.2 illustrates bridging.

Figure 5.2 - Bridging



Subflooring - Subflooring is the first layer of material applied over the floor joists. The most common subflooring is some type of sheathing material, usually plywood, particle board, or waferboard. The material typically has a thickness of at least ½ an inch and is usually ⅝ or ¾ of an inch. Thicker material or dimensional lumber may also be used. The subflooring lies under the finish floor, which is the final layer of flooring consisting of vinyl flooring, carpeting, wood, linoleum, or other types of flooring.

Underlayment - The underlayment is a second layer of material attached to the subflooring to strengthen the floor. It is usually made of plywood. Sometimes a heavy subflooring is used and the underlayment is not necessary.

Placement of Floor Joists

Construction of a floor begins with attaching a sill plate to the foundation or basement walls. The sill plate is most commonly attached to the foundation with anchor bolts embedded in the concrete. Once the sill plate is bolted down, marks can be made on it to indicate the placement of joists. The spacing of joists varies with the weight of the structure, dimensions of the material, and type of material.

After the sill is in place, the header joist should be cut to length and nailed in place along the outside perimeter of the sill plate. The header joists should be attached standing on the 2-inch edge of the board. They will then form a box sill. Header joists tie the other joists together, increasing the strength of the floor.

The joists running the length of the floor are called stringer joists. The stringer joists are also set on edge and are fastened to the header joists using nails or screws. The joists are spaced an even distance apart, usually 16 inches measuring from the center of one joist to the center of the next. This spacing determines the final strength of the floor. If a joist will be below a weight-bearing wall, another joist should be placed against it for added strength.

If the joists are longer than 8 feet, support beams or girders are typically placed under the joists to help support the structure. When joists meet at a beam, a metal joist bracket and bolts are used to attach the ends of the two joists together.

Bridging is added between joists. Metal bridging pieces may be used, or boards may be cut and nailed in place to join the bottom of one joist with the top of the adjacent joist, forming an "X" between the two joists. Bridging decreases the movement of joists from side to side, allowing the floor to give when weight is placed on it. Cross bridging will also strengthen the joists, helping to support the weight of the structure.

Installation of Subflooring

Once the joists have been fastened together, the subflooring can be installed. The sheets of subflooring are placed at a 90-degree angle to the joists. The edge of the sheet should rest on a joist, covering half of the joist. Another sheet of subflooring can then be joined next to the first sheet, with both sheets attached to the joist. The sheets of subflooring should be placed with a gap of at least ⅛ of an inch between them. The gap will allow for expansion and contraction of the sheets due to temperature changes. If this gap is not included, the edges of the subflooring may work upward due to the pressure.

The sheets of subflooring are typically attached to the joists with the fasteners about 8 to 12 inches apart. Using more fasteners will decrease later "squeaking" from subflooring that is loose and moving up and down against another sheet or the shank of the fastener. If extra holding strength is desired, glue may be placed on the tops of the joists before the subflooring is laid down.

When placing subflooring on a large floor, the place where the seams come together should be staggered or offset to give more strength to the floor. Staggering the seams may require cutting a smaller piece to start one strip of subflooring.

Load and Types of Flooring and Subflooring

Load is the weight carried by any part of a structure. Load can be classified into three categories: dead, live, and environmental. Dead loads refer to the vertical weight of a structure. They consist of the total weight of all the permanent parts of the structure, including the foundation, footings, lumber, and electrical and plumbing apparatuses. Dead loads act constantly. In contrast, live loads are considered to be temporary and intermittent. Live loads are the weight or pressure from static and dynamic loads. Static loads come from anything occupying the structure, such as livestock, equipment, or stored products. Dynamic loads come from the operation of equipment like a tractor or handling equipment in the structure. Environmental load is caused by natural factors, such as wind, snow, and earthquakes, that result in weight or pressure on a structure.

To determine what materials and spacing to use in the flooring, calculate dead load plus the maximum expected live load. If the floor will be supporting average loads, the joists can be placed 16 inches apart with ¾-inch subflooring. If heavier loads will be placed on the flooring, the joists should be spaced only 12 inches apart with 1-inch subflooring. For heavy loads, two layers of subflooring will often be placed on the joists for additional strength, increasing the thickness of the subflooring to 1½ inches or more. The second layer of subflooring is placed at a 90-degree angle from the first layer. Heavier loads also will generally require wider joists, and 2" × 12" joists can be used if the loads are very heavy. For heavy loads, metal members, large timbers, or combinations of metals, dimensional lumber, and possibly plywood are needed to construct floors. Several sources of information are available to help select the right materials and construction for different loads. Tables are available in many construction reference books to determine the ideal components for a building's total load. Most manufacturers of the materials used for this type of construction have recommendations that either are on the material or are made available by their retailers. Commercially prepared plans usually contain all the information necessary to purchase suitable materials and construct a building.

Summary

Floor framing forms the base of a building and attaches the structure to its foundation. Floors consist of many members that must be carefully constructed in order to provide the proper support for the structure. Loads will determine what materials are used and how the floor is constructed.

Credits

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Lesson 6: Walls

Walls add to the structural integrity of the building and increase weather protection. This lesson will describe some basics of wall construction and types of walls in common use. The focus is on wood construction, although metal is generally used in the same manner for frame construction.

Three Purposes of Walls

Although walls may serve many specific purposes, they have three main functions. They support vertical loads, which consist of pressure from the weight of the walls and the roof exerted downward due to gravity. Walls also resist lateral loads, or pressure exerted from the side. Lateral loads are produced by wind and other weather and by uneven settling of the building, which causes the wall not to be vertical. Finally, they provide protection from the weather. Walls are able to achieve these purposes because of the materials they are made from and how they are constructed.

Types of Wall Construction

The two types of wall construction that are common in agricultural structures are pole frame and stud frame construction. Pole frame construction, which is illustrated in Figure 6.1, involves the use of fewer but heavier members. Poles or posts form the main structural members of the wall. Horizontal pieces of dimensional lumber called laths or girts are attached to the poles. Siding, usually metal sheets or dimensional lumber, is placed vertically on the structure by attaching it to the laths.

Stud frame walls use studs, which are the vertical wall members that provide the main support for the wall, in their construction. The methods of construction used for wood or metal stud frame walls are similar. The spacing and size of the members, material used for siding, and interior cover materials are the major differences. Figure 6.2 shows an example of a stud frame wall.

Figure 6.1 - Pole Frame Construction

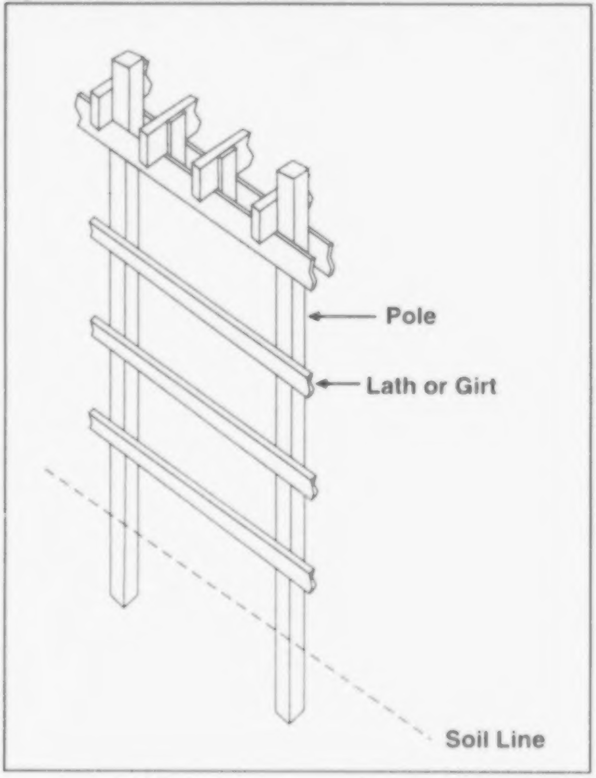


Figure 6.2 - Stud Frame Wall

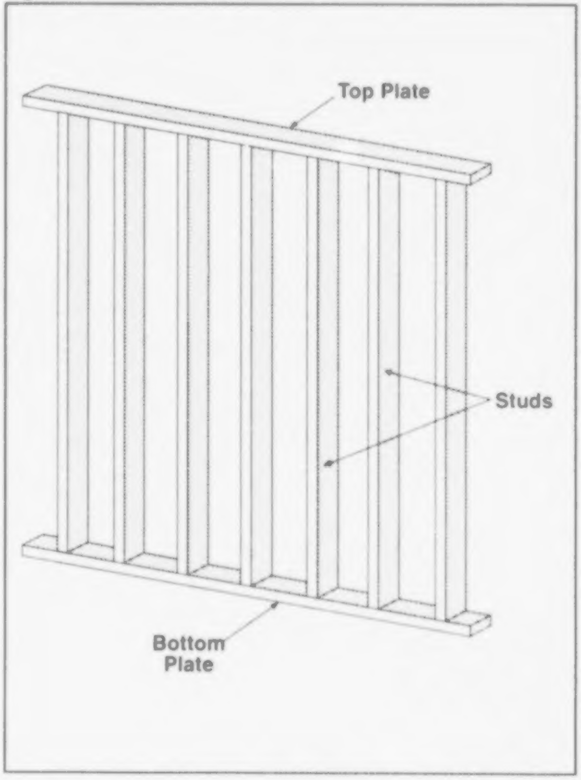
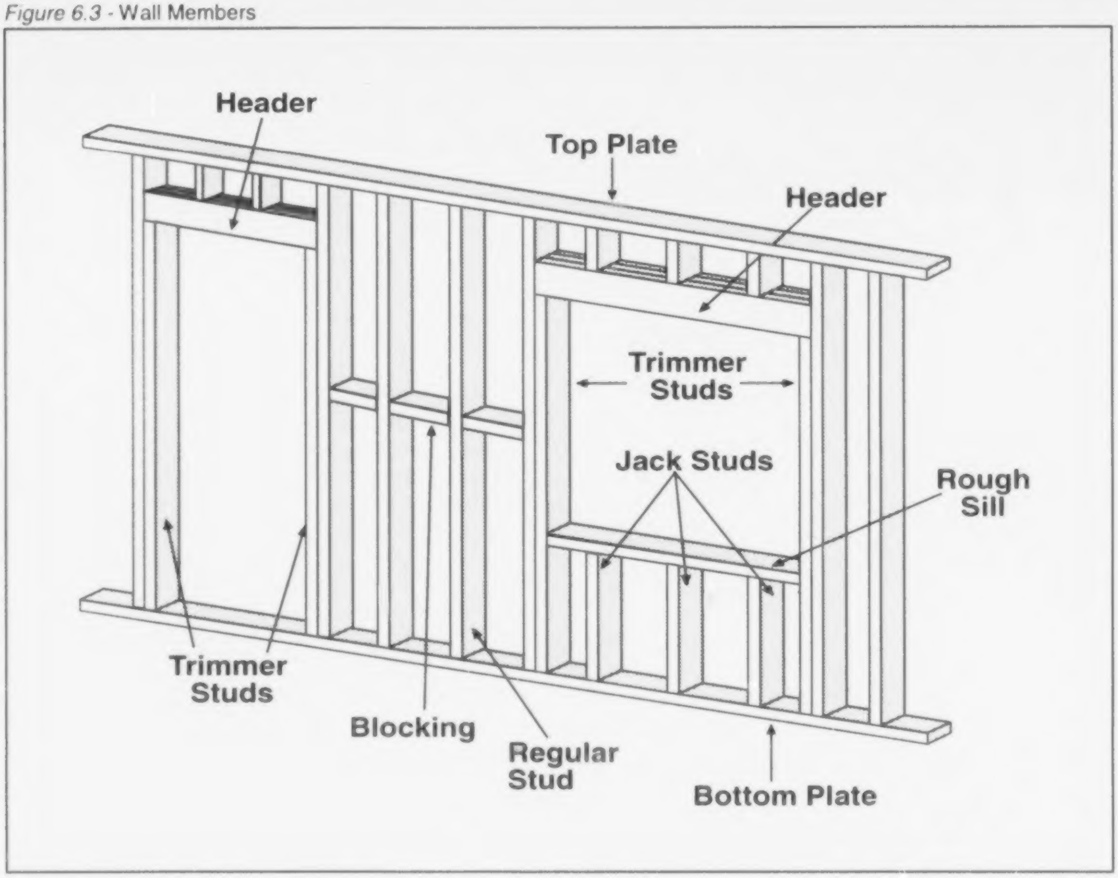


Figure 6.3 - Wall Members



Components of a Frame Wall

Frame walls consist of a number of structural components. Figure 6.3 illustrates different wall members.

Top plate - The top plate is the horizontal member at the top of the wall. The trusses or rafters rest on the top plate.

Sole plate - This structural member forms the bottom of the wall. The studs are nailed to the sole plate.

Stud - As discussed in the preceding section, a stud is the vertical wall member that provides the main support for the wall. Studs, which may be made of metal or wood, are nearly always placed on 16 or 24-inch centers to take advantage of commercial sheathing material dimensions.

Diagonal brace - Diagonal braces temporarily add to the rigidity of the wall, making it stronger. The bracing is used during wall construction to keep the walls square and vertical. To form the brace, a 2" board is nailed diagonally from a top corner to the opposite bottom corner of the wall. The braces are removed later as the siding and sheathing are put on the wall.

Header - A header is a horizontal piece found above openings for doors and windows. It provides support for loads over the opening.

Trimmer stud - Trimmer studs are vertical framing members that form the sides of door and window openings as well as rough openings. They support the header.

Jack stud or cripple stud - Jack studs are studs that are shorter than full length used below windows and above windows and doors.

Rough sill - A rough sill is a horizontal framing member attached to the top of the jack studs to form a rough base for a window.

Blocking - Blocking refers to the wooden blocks that are used to fill in the space between framing members, providing support.

Siding - Siding is material placed on the outside of a building to seal and enclose the building from the weather, serving as insulation for the structure.

Interior covering - This covering consists of material placed on the inside of the wall. Generally sheetrock is used for houses, while barns and other buildings may use plywood.

Wall Construction

Walls are typically constructed one wall or section of a wall at a time, with the wall laying flat on the ground. To begin construction, the length of the wall is determined, and the top and bottom plates are cut to that length. The studs are nailed between the top and bottom plate using two nails at each end of the stud. They are spaced an equal distance apart, usually 16 inches. The spacing of the studs determines the overall strength of the wall and its ability to support the weight of additional floors or the roof. Buildings with less weight on the walls are sometimes constructed with the studs 24 inches apart. At the corners of a building, double studs are nailed side by side. These double studs allow the two walls that form the corner to be attached to each other by providing a wider base to which to nail the 2" × 4" stud from the other wall. Diagonal braces and blocking attached between the studs add to the rigidity of the wall, making it stronger. When the wall is finished, it is stood upright and attached to the foundation or subfloor using nails or bolts. Walls are then nailed together at the corners. Finally, the diagonal braces can be removed.

If the wall has windows or doors, they require additional components. Window framing usually requires a header as well as extra support from trimmer boards at the sides of the opening. Window openings generally also use jack studs and a rough sill, as shown in Figure 6.3. Like window framing, door framing involves the use of a header, extra supports on the sides, and sometimes jack studs.

Types of Siding

Dimensional lumber is sometimes used as siding. The siding may consist of 1" × 12" boards or other similar sizes. Dimensional lumber accepts paint or stains readily, allowing customization. The lumber will degrade due to weather. However, it can be treated to be weather resistant, increasing the life of the lumber.

Exterior plywood is also used as siding. Because it is sold in larger sheets, fewer seams will exist, aiding in insulating the building. The plywood is also easier to apply than dimensional lumber. The plywood is cheaper than other forms of siding, but it is also not as attractive.

Hardboard sheathing, also called Masonite, may be used for siding on buildings. This style of sheathing is sold in sheets that come in a number of colors. Hardboard siding provides some insulation and is relatively easy to apply. One disadvantage to this style of siding is that hardboard is somewhat brittle and does not easily withstand stress from impacts, temperature changes, and other factors.

Metal siding, which is commonly made of galvanized steel or aluminum, is frequently used on structures. The siding comes in sheets that are normally at least 3 feet wide and 8, 10, or 12 feet long. The advantage to this sizing is that there are fewer seams, allowing for better insulation and weatherproofing than with other types of siding. Metal siding lasts for a very long time and does not need to be replaced as often as wood. Metal siding can be painted but not stained.

Vinyl siding is commonly used on houses and garages. This style of siding consists of strips that overlap, sealing the building. The siding is available in a variety of colors. Vinyl siding has a relatively long life but is more expensive than other types of siding.

Masonry products like bricks and cinder blocks are sometimes used as siding. They have decorative value and last for an extremely long time. The cost of the materials is moderate, but masonry products are more difficult to apply.

Fiberglass, glass, and plastics are used as siding in certain situations. One common example is a greenhouse, where light in the building is desirable. These materials can be purchased with varying levels of clarity, from totally clear to mostly opaque.

New siding materials are being developed and marketed. Many of these products are simply improved versions of traditional materials that might offer benefits such as a heavier weight or more weather resistance. Some products, like fiberglass/epoxy glazes that are sprayed or troweled on a surface, are the result of technological advancements.

When selecting siding, consider the grades and weights available, the fire resistance of the material, its expected life span, and its maintenance requirements. Manufacturers and retailers should have additional information on the specific advantages each type of siding may offer.

Summary

Walls serve to support the structure's vertical and lateral loads as well as to protect the inside of the building from the weather. Walls generally are constructed using either pole frame or stud frame construction. Stud frame construction is the more complicated of the two; frame walls consist of a number of components. While many siding options exist, most frequently some type of metal, vinyl, or wood product is used.

Credits

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Lesson 7: Roof Support Systems

Roof support systems in agricultural structures generally involve some type of rafter system. This lesson will explore the different components of rafter systems, their function, and their construction. An overview of different styles of roofs will be presented as well since roof styles are determined by the roof support system's configuration.

Trusses and Rafters

A truss is a structural assembly of lightweight material consisting of connected triangles formed by rafters, joists, or beams that is used to create a system designed to support heavy loads over a considerable span. Trusses may be made of wood, wood products, metal, or a combination of any or all of these materials. Truss designs will vary depending on the needs of the structure. For the purposes of agricultural construction, trusses are nearly always prefabricated units designed for a specific structure that are transported to the construction site and mechanically placed in position on the structure. Figure 7.1 is an example of a truss.

A rafter is a structural member that spans from a wall's top plate to the ridge board of the roof to support the roof, as shown in Figure 7.2. In common terminology, rafter generally describes a site-built truss-type system. As shown in the Figure 7.1, rafters are part of a truss system, and a "trussed rafter" is the correct term for a truss.

Selecting a Roof System

The ability to safely support roof loads, including live loads from ice, snow, or wind and the dead load of the material, is critical to a roof support

Figure 7.1 - Truss

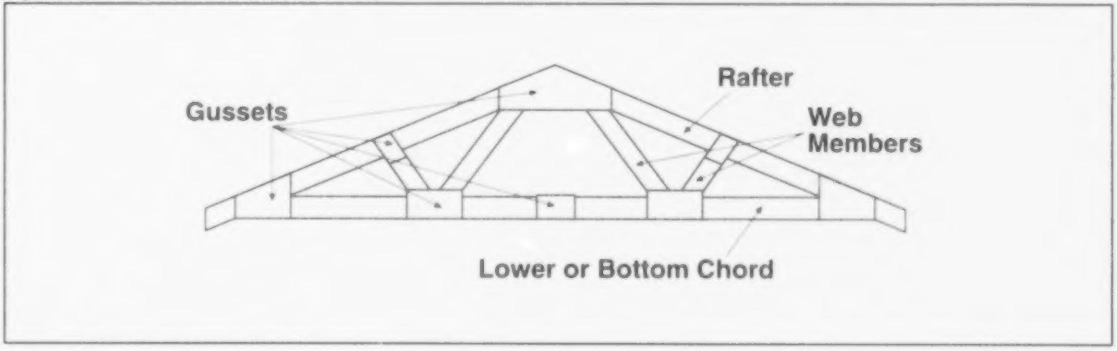
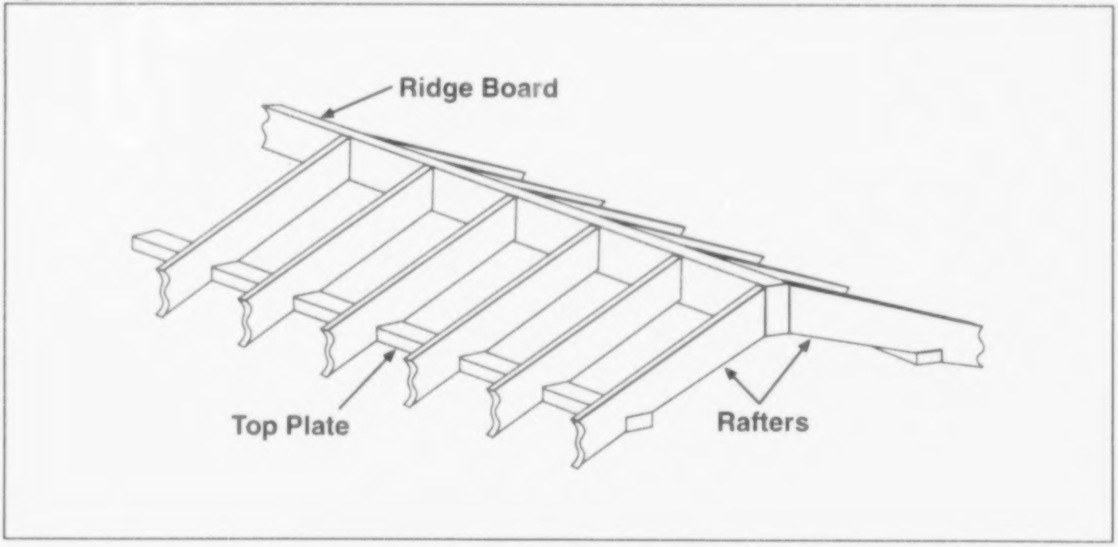


Figure 7.2 - Rafters



system. Load is therefore an important consideration when selecting a roof system. The choice of a roof system will vary depending on the weather of the geographical area, which will determine the wind and snow loads on the structure. Different materials and roof designs have varying load capacities. General information about load and roof systems is available from construction reference materials or in professionally prepared construction plans. In recent years, the industry of prefabricated trusses has eliminated much of the need for working with this information. Reputable truss companies have engineers or other professionals on hand to design roof support systems for specific structures.

The economics of cost and labor are another factor to consider when selecting a roof system. Truss companies will build to order, and generally they provide this service at a cost equal to or less than the cost of manufacturing systems on site. Roof support systems for smaller structures may be built on site at a savings, however. When making these decisions, the labor involved in cutting and assembling systems as opposed to buying prefabricated units must be considered.

Pitch

Pitch is a term used to describe a roof's steepness. The pitch of a roof can be flat to very steep. Architects, engineers, or other building professionals can determine if a given pitch is acceptable for supporting loads and provides an efficient use of material.

In order to calculate pitch, the rise and run of the roof must be known. Rise is the vertical distance from the top plate to the ridge. Run is the horizontal distance covered by one rafter from the outside edge of the top plate to the exact center of the ridge. Span is the total distance from the outside edge of one wall to the outside edge of the other wall. Span is equal to twice the run. All measurements of rafters are made relative to a measuring line that runs parallel to the side of the rafter and extends from the middle of the ridge board to the outer edge of the top plate.

Table 7.1 - Pitch and Slope

Pitch	Slope
1/8	3:12
1/6	4:12
1/4	6:12
1/3	8:12
1/2	12:12

Pitch may be defined as a fraction that is a ratio of the rise to the span. Pitch may also be expressed as slope in a ratio of the number of inches of rise per foot of run. Table 7.1 shows relationships between pitch and slope. An example of slope is 6 in 12, or 6:12, meaning six inches of elevation for every twelve inches of length, as shown in Figure 7.3. As illustrated in the diagram, slope is shown using an inverted right triangle and the accompanying rise and run numbers.

Common slopes for a roof are 4:12, 5:12, and 6:12. Buildings where snow buildup or storage space above trusses is not a concern commonly use 4:12 slopes, because the roof does not need to be as steep. A slope of 6:12 is used where storage space is desirable or snow loads are heavy.

Figure 7.3 - Pitch

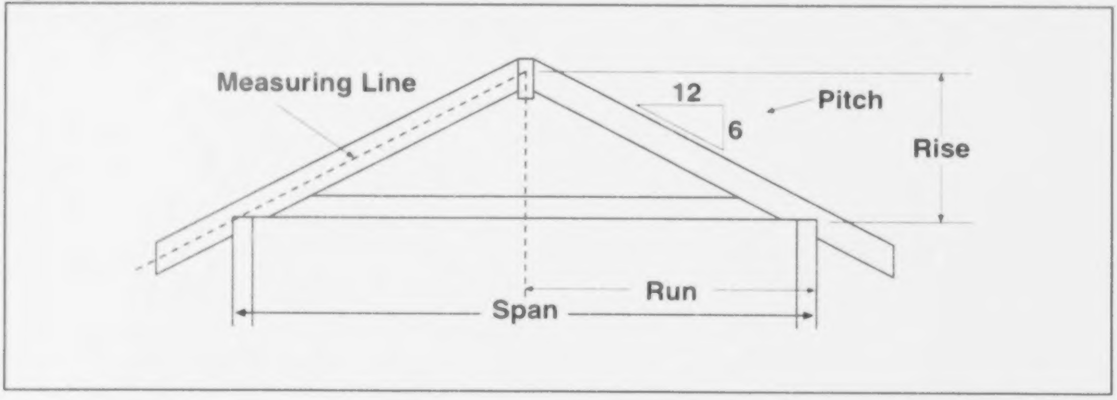


Figure 7.4 - Parts of a Rafter

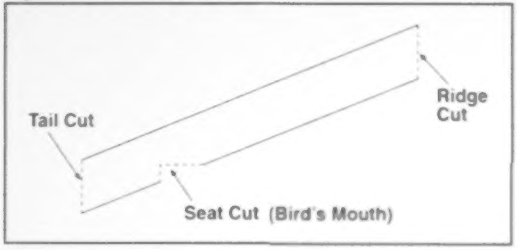
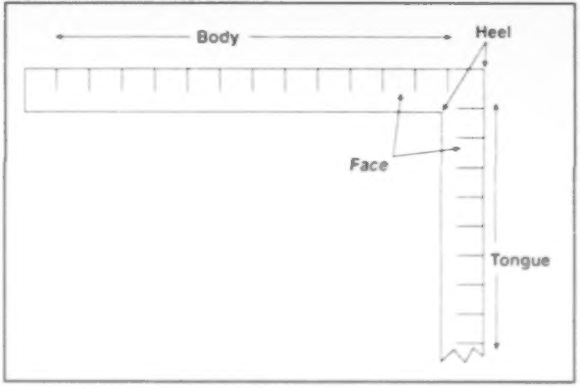

Tail Cut
Ridge Cut
Seat Cut (Bird's Mouth)

Figure 7.5 - Framing Square


Body
Heel
Face
Tongue

Calculating Pitch

When expressing pitch as a fraction, the degree of pitch is calculated using the formula shown. A roof with a rise of 6 feet and a run of 12 feet has a pitch of ¼.

$$\text{Pitch} = \frac{\text{Rise}}{2 \times \text{Run}}$$

Parts of a Rafter

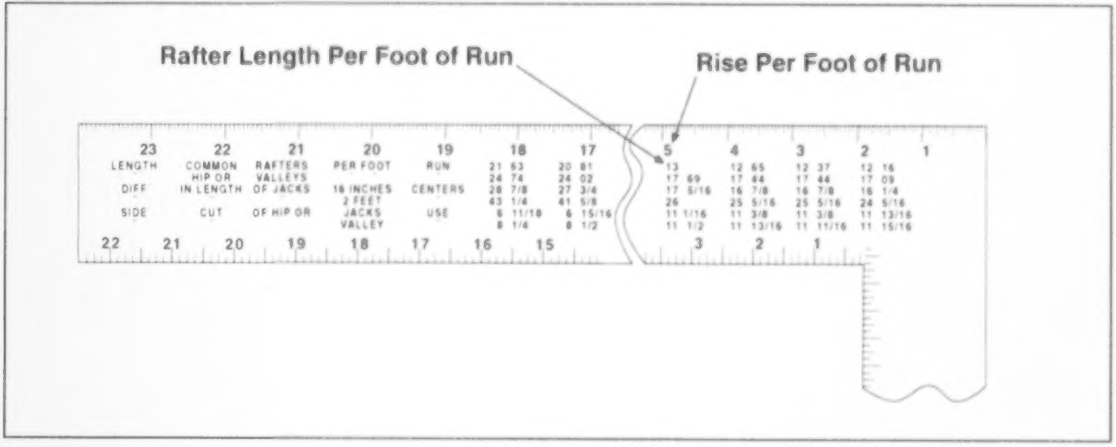
A rafter is a piece of dimensional lumber that constitutes the main member of a roof support system. Rafters are commonly made of 2" × 8" or 2" × 10" boards in the desired lengths. The tail, or overhang, is the part of the rafter that forms the part of the roof from the side of the building to the end of the roof. The other parts of a rafter are the cuts made to allow the rafter to fit properly in the roofing system. Rafters have three kinds of cuts, as illustrated in Figure 7.4, which shows the positions and angles of these cuts. A tail cut is made at the end of the rafter and is parallel with the wall. A seat cut, sometimes referred to as a bird's mouth, is a notch cut out of a rafter that allows the rafter to be seated on the top plate. The ridge cut, also called a plumb cut, is made at the end of the rafter that fits against the ridge board and allows the rafter to fit flush against the ridge.

Rafter Layout

Rafter layout most commonly involves the use of a framing square (Figure 7.5). The face of the square is the side seen when holding the tongue of the square in the right hand with the body pointing to the left, as in the illustration. Various tables and scales are found on this versatile tool. Even inexpensive squares include tables for rafters and graduated scales of 1/6, ½, ⅛,and ¼, which are common pitches. These scales provide specific information on laying out cuts for these pitches.

The rafter table, shown in Figure 7.6, is used to determine the length of the rafter. To lay out a

Figure 7.6 - Rafter Table


Rafter Length Per Foot of Run
Rise Per Foot of Run
23 22 21 20 19 18 17 5 4 3 2 1
LENGTH COMMON RAFTERS PER FOOT RUN
HIP OR VALLEYS
DIFF IN LENGTH OF JACKS 16 INCHES CENTERS
2 FEET
SIDE CUT OF HIP OR JACKS USE
VALLEY
21 63 / 24 74 / 28 7/8 / 43 1/4 / 6 11/16 / 8 1/4
20 81 / 24 02 / 27 3/4 / 41 5/8 / 6 15/16 / 8 1/2
13 / 17 69 / 17 5/16 / 26 / 11 1/16 / 11 1/2
12 65 / 17 44 / 16 7/8 / 25 5/16 / 11 3/8 / 11 13/16
12 37 / 17 44 / 16 7/8 / 25 5/16 / 11 3/8 / 11 11/16
12 16 / 17 09 / 16 1/4 / 24 5/16 / 11 13/16 / 11 15/16
22 21 20 19 18 17 16 15 3 2 1

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rafter, the rise and the run are needed. First, the number that indicates the rise per foot of run on the "inch" line on the body of the framing square must be located. In the rafter table beneath this number is a number indicating the length of a common rafter per foot of run; a space between these numbers is read as a decimal point. This second number is multiplied by the number of feet of run. The desired length of the tail is added, and one-half the thickness of the ridge board is subtracted. After rounding as needed to the nearest ¼ inch, this number is divided by 12 to find the length in feet and inches.

As an example, suppose rise per foot of run is 5 inches. The table in Figure 7.6 indicates that the length of a common rafter with a rise of 5 inches is 13 inches per foot of run. The run for the roof, including the amount of projection, is 14 feet. Fourteen multiplied by 13 is 182 inches; subtracting 3/4 inches for half the thickness of the ridge board leaves 181.25 inches, or 15 feet, 1¼ inches.

Once the length has been established, the various cuts can be made on the rafter. The tail cut is made at the end of the board that overhangs the structure, as shown in Figure 7.7. The measuring line is marked in the center of the rafter material. Then the correct length of the rafter is measured and marked along the line. The square is placed on the material and the number 12 on the body is aligned with the top of the board to indicate the run. The framing square is pivoted until the number 5 on the tongue, indicating the rise, aligns to the top edge of the board. The outside edge of the tongue must be even with the mark made along the measuring line to represent the length of the rafter. The tail cut is marked along the outside edge of the tongue. The rafter is then cut.

The ridge cut is made in the same manner as the tail cut but at the opposite end of the material. Again, the outside edge of the tongue must be aligned with the mark indicating the length of the rafter found at this end of the measuring line.

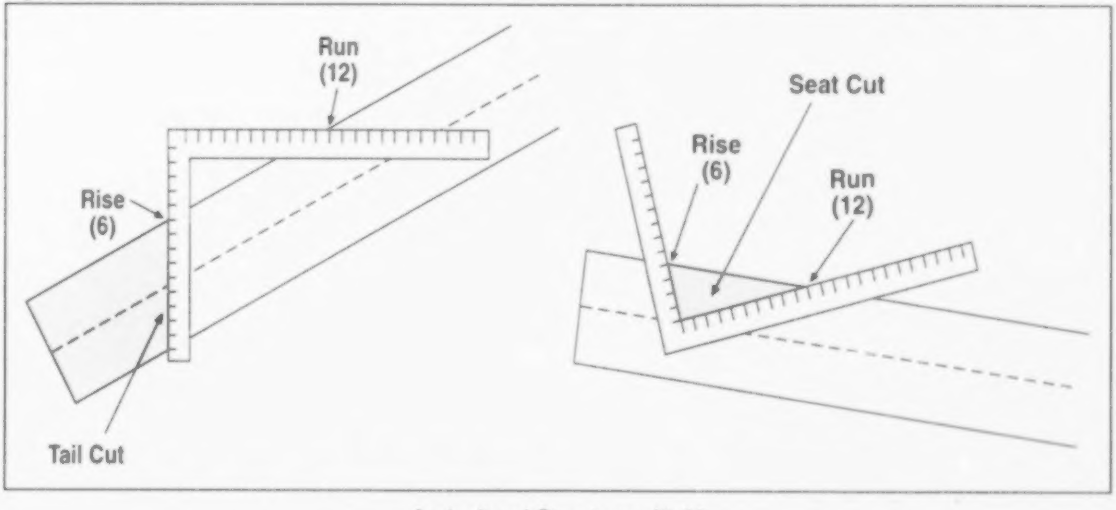
The seat cut is made by first measuring the length of the tail and marking this point on the measuring line. The depth of the seat cut is usually the same as the thickness of the piece of material used in the top plate, most commonly 1½ to 3 inches. The material with the edge to be cut is laid facing the opposite direction. The framing square is placed on the material with the body pointing to the right and the tongue pointing up. The inside edge of the tongue is aligned to the mark indicating the length of the tail and the tongue is adjusted until the rise and run correspond with the edge of the board. The wedge-shaped section is marked and cut out.

Constructing a Top Plate

The top plate is a wall member that is usually made of the same material as a wall's studs. It is attached to the top of the studs. Rafter seat cuts fit over the top plate, connecting the wall to the roof support system.

Top plate construction is generally a simple procedure. Dimensional lumber of the same size used for the wall studs, usually 2" × 4" or 2" × 6"

Figure 7.7 - Rafter Cuts



boards, is attached to the tops of the studs. Often a second piece of the same material is attached to increase strength and stability. If the top plate is doubled, the joints of the layers should not overlap; staggering the joints will further increase the strength of the structure.

Ordering Trusses

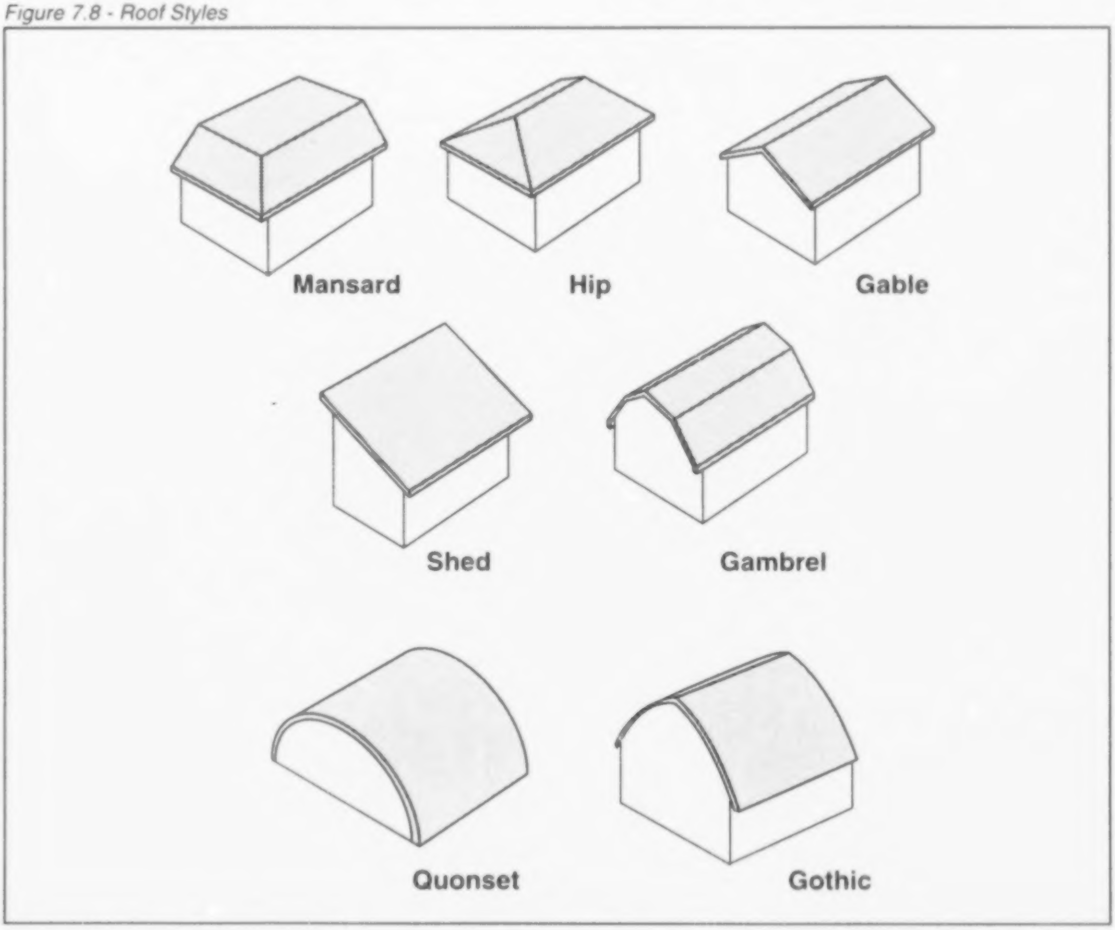
Ordering trusses is made easy with the help of professional representatives from the manufacturer. These people are able to make suggestions and explain the options. Perhaps the most important information to supply to a truss manufacturer is a copy of the building's plans, which will provide all the technical information needed, including span, run, rise, and pitch. The builder will probably also want to be told the type of roofing material to be used, although this information may not affect the design. Other important information the truss manufacturer will need is the desired delivery date and time and, if a representative has not been on the building site, exact directions.

Roof Styles

The most common types of roof styles used in agricultural structures are shed, hip, gable, gambrel, mansard, quonset, and gothic, or arched. (Figure 7.8). These roof types were introduced in Lesson 2 of this unit. Any of these styles or combinations of styles may be found in most areas. As was previously discussed, the choice of a particular roof style is based on the structure's function, personal preferences, and affordability If proper planning and materials are utilized, all the roof styles are comparable in function in regard to protection from the elements.

Shed - A shed roof has only a single pitch. This type of roof is usually found on smaller structures

Figure 7.8 - Roof Styles



of 2,000 square feet or less. It has the advantage of being inexpensive to construct and simple to frame and install. Because the slope of the roof is relatively shallow, it is able to resist winds well.

Hip - Hip roofs have an attractive appearance. However, they are difficult to frame and install. Poor ventilation of attic areas can also be a problem.

Gable - Gable roofs are very common and are often used for agricultural structures. They are relatively inexpensive and easy to frame. If the pitch of the roof is not too steep, this design may be extremely wind resistant.

Gambrel - Gambrel roofs use two different pitches, with the top pitch being approximately 30 degrees and the bottom pitch around 60 degrees. It is used for barns, because the design provides the advantage of spacious overhead room for storage. However, these roofs can be expensive and are more difficult to construct. They also are less resistant to damage from winds.

Mansard - Like hip roofs, the mansard roof style is regarded as having an attractive appearance. One potential problem with this type of roof is that it leaks more easily because of the shallow pitch of the roof.

Quonset - A Quonset structure has no flat surfaces. Instead, the structure forms a semicircle with an arching roof. Quonset buildings are usually sold as a package and are therefore easy to construct.

Gothic/arched - In a Gothic or arched roof, two curving arches meet at a point. Some structures with this type of roof are similar to Quonset buildings in that they have no walls; the arches make up the sides of the building as well as the roof. However, a Gothic roof may be used for other types of buildings, such as barns, that do have distinct walls. The arches create a strong roof with large storage volume.

Summary

Roof support systems generally consist of either trusses or some other type of rafter system. Systems may be prefabricated and ordered from a manufacturer or built on site. The type of roof system chosen will depend on load, cost, and labor considerations. One important aspect to consider for any roof is its pitch, or steepness. Several different roof styles may be used.

Credits

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Lesson 8: Roofing Materials

Roofing materials come in a variety of forms. For agricultural structures, three types of roofing materials are commonly used. While all of them can offer good protection from the weather, each has its advantages and disadvantages.

Types of Roofing Materials

The three types of roofing materials most commonly used in agricultural structures are fiberglass shingles, asphalt in roll or shingle form, and metal roofing. Asphalt is a combination of crushed rock and an adhesive. Asphalt shingles are used extensively on homes. Metal roofing can be made of steel, tin, aluminum, or copper. Steel roofing is commonly used and is available in either galvanized or painted form. Galvanized metal is metal that is coated with zinc oxide to prevent rusting. Painted or galvanized metal roofing is commonly used on machine sheds and other agricultural structures. Other materials, like cedar shingles or tile, are sometimes used but generally only for cosmetic reasons; they can be quite costly.

Roofing material is sold by the square, a square being equal to 10 feet by 10 feet, or 100 square feet of finished roofing. The delivery of roofing materials to the work site is often an option and may be worthwhile, since most delivery trucks are equipped to deliver materials to the rooftop, which is an advantage when dealing with a large amount of roofing material. Knowing the roofing material's warranty and how the roofing must be installed to comply with the warranty agreement is important. Factors such as proper roof ventilation may be required if the warranty is to be valid.

Advantages and Disadvantages of Roofing Materials

Before choosing a roofing material for a particular structure, the advantages and disadvantages of each type of material available should be assessed. Longevity, cost, and maintenance requirements are some factors used when evaluating roofing materials.

Asphalt roofing material has the advantage of being lower in cost than either metal roofing or fiberglass shingles. Asphalt in roll form usually costs the least of the different types of roofing materials discussed in this lesson; it is often considered the least attractive as well. An advantage of asphalt in roll form is that installation is simple. A disadvantage of asphalt roofing material is its relatively brief life span in comparison with the other types. While different brands may vary in their life span, under normal conditions they last for 15 to 25 years. Proper maintenance will involve refastening materials that come loose and repairing any leaks that develop. Another disadvantage of asphalt roofing is that it will burn readily.

Fiberglass shingles are moderate in cost; they are more expensive than asphalt products but cost less than painted metal roofing materials. They also have a longer life span, around 30 years. A disadvantage of fiberglass shingles is that they are flammable. Again, maintenance involves keeping shingles fastened securely and any leaks repaired.

Galvanized metal comes in a variety of lengths, gauges, and ribbings, which are raised areas in the metal that add strength. The material is relatively inexpensive, being comparable in price to asphalt roofing. It is very fire resisiant and has a life span of 50 years or longer. Galvanized metal is a very durable material, and maintenance requirements are limited to simply keeping it tightly secured to the roof. To increase its life span, the metal may be coated with rust-retardant roofing protectant, although this material may not be needed for years after the roof's initial installation. A disadvantage of galvanized metal is its plain silver appearance, which may not make it suitable for all uses. Another disadvantage of metal roofing is the noise caused by rain or hail striking the roof, especially in a building inhabited by people or animals, like a house, office, or barn. Noisy barns can be unsettling to some animals, especially hogs.

Like galvanized metal, painted metal comes in a variety of lengths and gauges. However, as its name indicates, it comes in a variety of colors and can be attractive. It is also fire resistant and can have a long life span of 30 or more years, depending on the gauge, finish, and maintenance. Painted metal roofing is generally more expensive than asphalt shingles, galvanized metal, or fiberglass roofing.

Maintenance for both types of metal roofing generally involves keeping the material secured tightly to avoid leaks and keep the wind from tearing off the metal sections. In some locations, periodic washing of the roof may extend the life span considerably. In areas where trees overhang the roof, leaves or bird droppings may accumulate and have a caustic effect on the metal, causing premature rusting.

Structural Components of a Roof

The structural components of a roof include the rafters or trusses that make up the roof support systems discussed in the previous lesson. In addition, roofs using asphalt or fiberglass roofing materials consist of a solid decking system to which the roofing material is attached. The decking may be either some form of sheathing material, such as plywood or oriented-strand board, or dimensional lumber, usually ¾" thick. The decking is nailed or screwed over the top of the roof support system.

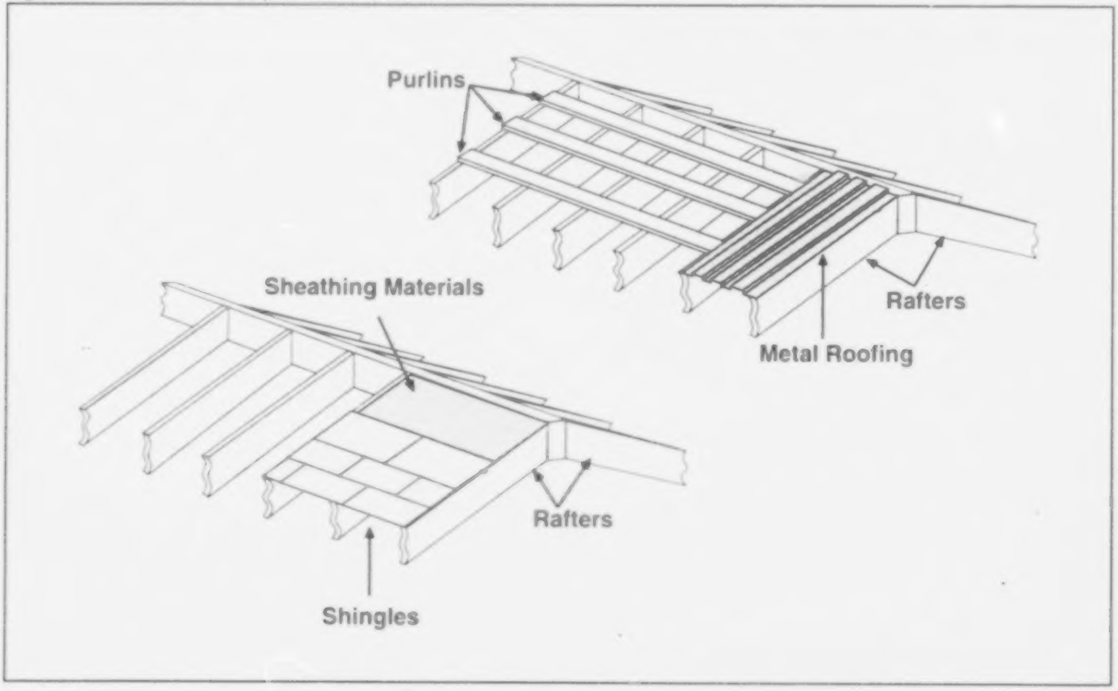
Metals may be installed over solid decking, but using decking would increase the cost and weight of the roof system. Instead of decking, purlins are used. Purlins are pieces of dimensional lumber, commonly 1" × 4", in varying lengths. The purlins are nailed perpendicular to the rafters. They provide a surface to which the metal roofing is attached. The spacing of the purlins is dependent on many variables, such as the roof span, the strength of the material used for the purlins, and pitch. Figure 8.1 provides an illustration of the structural components of both types of roofs.

Attaching Roofs

Roofing material in roll or shingle form is usually fastened with galvanized or sometimes aluminum nails. These materials resist rusting, which can cause rust-colored stains on the roof. The nails are usually 1¾ inches long, although their length can vary according to the application or the recommendation of the manufacturer of the roofing material. They have a large, flat head to hold the material securely and resist tearing the shingle. Nails are usually used at a rate of approximately 1⅞ pounds of nails per square of roofing material. Shingles may also come with an adhesive on them to help secure them to the decking. The adhesive is often covered with a paper strip that is pulled off at the time of installation.

When attaching asphalt shingles, one of the most common types of roofing, the first step is to nail or staple a layer of building felt, or underlayment, to the roof. Building felt is a tar-soaked fabric that will repel water. It helps to seal the building and

Figure 8.1 - Structural Components of Roofs



prevent leaks. The felt is placed across the length of the roof horizontally starting at the bottom of the roof, with successive layers overlapping about 4 inches. A special metal strip called a drip edge is applied to the bottom and sides of the roof over the underlayment. It prevents moisture from seeping under the underlayment, which would lead to mold or rot.

After the felt and drip edge are in place, the shingles can be applied to the roof, starting at the bottom. Each successive layer or course of shingles will overlap the layers below, allowing water to drain off without the roof leaking. Two types of shingles, T-lock and three-tab shingles, may be used on roofs, although three-tab shingles are the most common.

When attaching three-tab shingles, the first course, or starter course, is made of half shingles. The shingle is cut lengthwise along the top of the tabs, making it rectangular. The first shingle in the starter course will need to be cut to a length of 30 inches to offset the end with the first course of full shingles, as shown in Figure 8.2. The long edge of the shingle is placed along the bottom edge of the roof as square to the edge as possible. A hand level should be used to make sure the first course is level. Nails should be applied in the sealer strip that runs lengthwise above the grooves or weeps in each shingle, with one nail on each end of the shingle and above each weep (four or less per shingle).

Once the starter course is down, the remaining courses can be laid. The starter course will be completely covered by the first course of full shingles. The shingles in each remaining course overlap the previous course halfway, or just above the top of the weeps. The weeps of each course should be equally staggered from the previous course to form a brick-type pattern, illustrated in Figure 8.3. To do this, the first shingle in each course needs to be cut in six-inch increments, producing shingles that are 30, 24, 18, 12, and 6 inches long. These shingles are then laid out along the side of the roof in sequence, starting with a full shingle (36 inches long) and continuing across the roof with full shingles to the other side. The last shingle in the course will be cut even with the side of the roof. The second course will start with a 30-inch shingle, the third with a 24-inch shingle, and so on, creating a pattern that is repeated every six rows. The cut-off material at the beginning of each course may be used at the other end of a course. Any pieces over 12 inches long (a full weep) may be used on the peak of the roof.

Figure 8.2 - Starter Course for Three-Tab Shingles

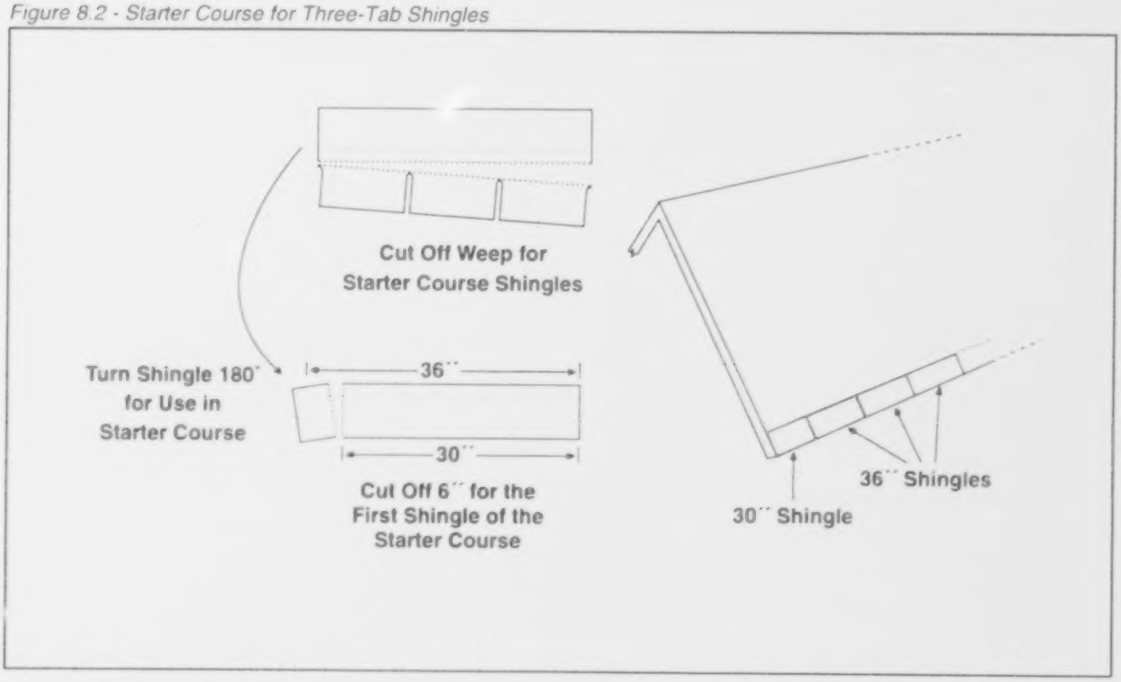
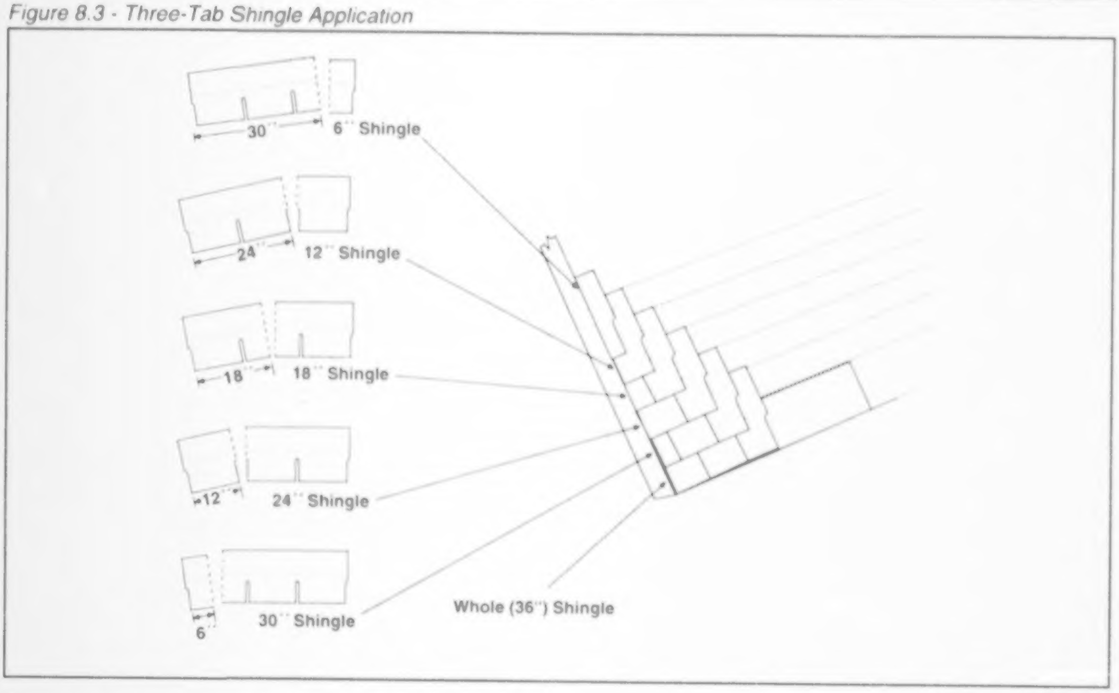

Cut Off Weep for Starter Course Shingles
Turn Shingle 180° for Use in Starter Course
36"
30"
Cut Off 6" for the First Shingle of the Starter Course
36" Shingles
30" Shingle

Figure 8.3 - Three-Tab Shingle Application

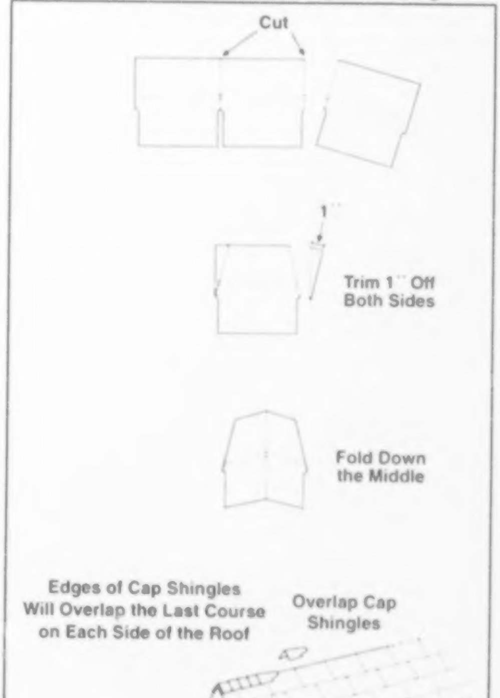

30"
6" Shingle
24"
12" Shingle
18"
18" Shingle
12"
24" Shingle
6"
30" Shingle
Whole (36") Shingle

Two methods are used to finish the cap or final course covering the roof's peak. One method is to cut three-tab shingles into three sections and lay them across the peak overlapping the top courses on each side of the ridge. Figure 8.4 shows how to cut a full shingle for cap shingles and how each cap shingle should be trimmed prior to attaching it to the roof. Another method involves using special pre-made cap shingles on the peak.

Whichever method is used, these shingles must also overlap each other to prevent rain from getting under them. The direction of overlap depends on the normal wind direction. If the wind is commonly from the north, the shingles should start at the south end of the roof. This will leave exposed edges of the cap shingles facing south, where the wind and rain cannot get under them as easily.

Galvanized or painted metal roofing is most often installed with ring shank screws or nails. These fasteners come with a neoprene or lead washer attached. They are generally 2½ inches in length. When attaching the roofing materials, the ribbing running the length of the material is overlapped. The nails or screws are then placed through the ridges of the roofing material, not in the flat areas. The placement of fasteners will vary depending on the type of ribbing; the manufacturer's

Figure 8.4 - Forming and Applying Cap Shingles


Cut
1"
Trim 1" Off Both Sides
Fold Down the Middle
Edges of Cap Shingles Will Overlap the Last Course on Each Side of the Roof
Overlap Cap Shingles

recommendations, which are usually printed on labels for the roofing, should always be followed. The fasteners are generally used at rate of 1½ pounds or 100 fasteners per square. When working with metals, aluminum and galvanized metal materials should not be used together. This combination will result in an electrolyte reaction that quickly causes corrosion.

Summary

Roofing materials for agriculture structures will generally be made of asphalt, fiberglass, or metal, and each material has its advantages and disadvantages. Roofing material is applied to either a solid decking surface or a purlin system that is attached to the top of the rafters or trusses. The material must be attached carefully using the proper technique to ensure that the roof is secure and watertight.

Credits

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Lesson 9: Heating, Cooling, and Ventilation

Heating, cooling, and ventilation needs in agricultural structures vary according to the uses of the structure. All structures are affected to some degree by these factors. However, for some structures, they must be carefully regulated for the structure to serve its intended purpose.

The Purpose of Insulation

Agricultural structures that serve to shelter anything that is sensitive to temperature must allow the environment of the structure to be regulated. Animals can only survive and function within a certain range of temperatures. Many chemicals must be kept at certain temperatures to remain usable and safe. Machinery is also affected by temperature and may be damaged or cease to function if not provided with appropriate shelter. Insulation is one way that structures are equipped to regulate temperatures. The materials used for insulation are varied in form and application, but they all enhance a structure's ability to regulate temperature. Insulation should slow down or stop the movement of air between the inside and outside of a building. A properly insulated building can dramatically reduce the cost of heating and cooling because the temperature of the building does not fluctuate much once the desired temperature is achieved.

Insulation works by reducing and restricting heat transfer. It inhibits conduction and convection transfers. Conduction refers to the transmission of heat through solid matter because of contact between hot and cold areas, while convection transfers occur as heat moves through a liquid or gas. Insulation can also protect against heat transfer from radiant heat, which is given off by sources of heat, such as the sun. Radiant transfers are inhibited by the use of foil on the side of the insulation that faces an air space.

A particular insulation's ability to resist the transfer of heat through the material is usually expressed mathematically as an R-value. The higher the R-value is, the greater amount of insulation provided. As a general rule, a structure with insulation that has a high R-value requires less energy to maintain a desired temperature than a building with insulation with a lower R-value.

Types and Methods of Insulation

The insulation industry is progressive in the application of technology, and many different types of insulation are available for most applications. The choice of a particular type of insulation depends on factors such as cost, the suitability of the material for the application, and the adaptability of the insulating material to the structure. Cost is most often related to the insulation's R-value and the ease or efficiency with which the material may be installed. Usually, the higher the R-value, the more expensive a given material is. When considering the suitability of insulation for a particular application, one aspect that should be assessed is whether the insulation may come into contact with water from condensation or leaks, which can reduce its effectiveness. Water is detrimental to some forms of insulating material, while other materials may be water resistant but have a greater cost per unit of R-value. The structure's physical characteristics must also be considered when selecting insulation. For example, structures with solid walls of concrete or metal do not have a convenient space in which to place insulation.

When evaluating insulation, fire resistance and toxicity are also concerns. While some insulation is chemically treated to make it fire retardant, materials that are not fire resistant or that give off toxic fumes when exposed to flame should only be used in applications where they are covered with a suitable protective material, such as masonry. Also, some insulating materials may be irritating or toxic if physical contact occurs or they are ingested; these materials may be a problem in a structure that houses livestock.

Many different types of materials are used for insulation, which is available in a wide range of R-values and levels of fire resistance. Manufacturers create their own products by combining materials and treating them chemically; specific information about a particular type of insulation must be obtained from the manufacturer or retailers. Some commonly used natural or organic insulators include cotton, cellulose, shredded bark, shavings, sawdust, and straw. These insulators are made of natural materials and are generally cheaper. Manufactured materials used for insulation include fiberglass, rockwool, expanded mica, fiber board, cellular glass, expanded polystyrene, expanded polyurethane, urea formaldehyde, and polyisocyanurate. These insulators have a higher R-value per inch of thickness.

The methods by which insulation is applied vary. For example, depending on the method used, insulation may be placed between framing members or applied to the outside of the structure in the form of sheathing. Common methods of insulation include blanket, batt, rigid, and fill insulation.

Blanket - Blanket insulation consists of wide rolls of material, often with foil covering on one or both sides and an insulating material like fiberglass in the middle. This method of insulation is often used for insulating metal buildings and covering large sections of walls. The insulation is usually stapled to the inside walls of the structure on wide, flat surfaces.

Batt - Batt insulation is provided in rolls of material in precut sections, usually 4 to 8 feet in length and 16 inches wide with a thickness of 4 to 6 inches. However, the exact size of this material varies with the intended application. Batt insulation fits between the studs in the walls or other framework in structures and is fastened in place with staples.

Rigid - Rigid insulation is available in the form of sheathing, usually 4' × 8', in varying thicknesses. It can be made of a number of materials but is most commonly Styrofoam. It is often covered with foil on one or both sides. Rigid insulation is usually nailed in place on the outside walls of a structure before siding is applied.

Fill - The material for fill insulation is in a loose form, possibly small beads or a form resembling snowflakes. This type of insulation is generally made of fiberglass or expanded mica. It may come in bags that are simply emptied where needed, as in the cores of masonry blocks. Fill insulation may also be mechanically blown in place through a large hose that feeds the material to the desired place. Sometimes this type of material is mixed with chemicals to make it adhere to a horizontal or overhead surface and then blown into place.

The Importance of Ventilation

Ventilation is the movement of air through an area, either naturally, because of convection air currents, or mechanically. Poor ventilation can be unhealthy and dangerous. For example, methane gas, which can asphyxiate animals and may be explosive, is a by-product of decaying organic matter and can build up to hazardous levels in areas with inadequate ventilation. Fumes given off by some substances can be toxic if they accumulate in an enclosed space. Poorly ventilated buildings promote the growth and transmittal of disease-causing microorganisms because of increased temperatures and moisture levels within the structure. The ventilation of a structure will affect air temperature, moisture level, number of microorganisms, and concentrations of odor and gases. Proper ventilation can control temperature and moisture levels, thus reducing the growth of microorganisms. It can also diminish odor problems and prevent the accumulation of dangerous gases.

Windows and doors alone are often able to provide suitable ventilation and should be planned carefully since they can be a simple and economical way to ventilate a structure. Fans and blowers are also commonly used in agricultural structures to assist with ventilation. Mechanical ventilation can involve the use of elaborate systems with duct work and electronic thermostat switches to activate a fan or may be as simple as a window fan or roof-mounted turbine vent.

Ventilation is often effective at lowering temperatures. However, at times structures can become too hot even with ventilation. Animals may be unable to function well if a building is too hot; problems such as not breeding, weight loss, and terminated pregnancies may result. In these cases, mechanical cooling is necessary, although it may be costly. Water evaporative systems are sometimes used. These systems vaporize water, thus increasing the humidity while circulating the air and cooling the structure. Another option is the use of refrigeration systems (air conditioners), an expensive but effective solution if designed and used properly. Before installing equipment to cool a structure, the system should be considered carefully, and professional advice should be sought in most cases to avoid complications. For example, animals that depend on respiration to cool themselves can be adversely affected by temperature and humidity changes.

Types of Heating Systems

Supplemental heating is sometimes necessary in agricultural structures. Systems and designs vary, but as a rule, structures are heated using radiant, floor, or unit systems. Heat may also be produced by furnaces or boiler systems using air, water, or a combination of both as a transfer medium.

When radiant heating systems are used, radiant heat passes through the air until it comes into contact with an object, such as an animal, and passes on its energy as heat. It will not heat objects out of its path. Gas or electricity may be used to power these systems. An example is an infrared heater.

Floor systems are usually designed to heat specific areas, such as a nursery in a farrowing house. Hot water pipes or electric elements may be buried just below the surface of the floor. These systems may be powered by electricity, natural gas, or ground-source heat pumps, in which the ground heats the water.

Unit heaters are used to heat the air in a general area of a structure. These heaters often use fans to circulate the air after heating it. They may be powered by a variety of fuels, such as propane, natural gas, or electricity. Unit heaters are similar to the heaters found in large gymnasiums, shops, or stores, with a heating unit mounted overhead and a fan blowing the heated air from the heater.

Boilers and furnaces are large commercial appliances utilizing a system of pipes, ducts, or vents to transfer heat to where it is needed. Boilers heat hot water that is pumped to radiators, while furnaces heat air and blow it through ductwork to the rest of the building. They may be powered by fuels such as propane, natural gas, electricity, or wood.

One important term to understand when dealing with heating is BTU. BTU stands for British thermal unit; one BTU is equal to the amount of heat required to raise the temperature of 1 pound of water 1 degree Fahrenheit. This term is used when describing a system's heating ability.

Consulting with a heating professional is recommended when planning a large system. Safety concerns, such as the proper delivery of the fuel or power, ventilation for by-products like carbon monoxide, and potential fire hazards, makes the installation of heating systems a critical area of construction. The amount of heat needed as well as the cost of installation and operation are questions that must be answered accurately for the overall heating system to be suitable for the structure.

Feasibility of Solar Heating

The solar energy reaching the earth is estimated at 100,000 times the total of all the energy output from all existing power stations. However, this type of energy is not always easy to utilize effectively. Fortunately for all life on earth, this energy is quite diffuse by the time it reaches earth. Solar energy is also not consistent on a daily basis. These factors, as well as the cost of systems for collecting solar energy, have made solar heating a possibility but not often a first choice. At times when fossil fuel prices have risen sharply, as in the 1970s, a great deal of research into the applications of solar technology in the agricultural industry has taken place. However, as prices stabilized, research turned more toward efficient uses of fossil fuels since they provide very controlled and predictable energy amounts.

Passive solar heating is feasible if a building has a consistent solar exposure not obstructed by trees, other buildings, clouds, or other items that block the sun's rays. This type of heating makes greenhouses effective, as greenhouses utilize passive solar heat to maintain temperatures.

Passive solar energy can be used to help heat structures fairly simply. Orienting structures and windows to take advantage of solar energy is sometimes advantageous. Positioning a structure so that its south wall has windows and an unrestricted plane with no trees, buildings, or other obstacles will allow solar energy to enter the structure naturally. Covering the windows with an insulating material at sundown will help the structure to retain the heat. Strategically placing large water containers, such as 55-gallon barrels, or building with stone or masonry where they can be warmed by the sun will also help heat the structure. They act as storage units that collect and hold the sun's heat, releasing it back into the structure over a period of time.

Summary

Insulation reduces heat transfer through a building. Many different types of insulating material are available, and each type should be evaluated by considering the structure's needs and the costs, hazards, and benefits of the insulation. Ventilation should also be carefully evaluated since it can affect the safety of a structure. Another factor that should be considered when constructing a building is whether a heating systems is needed, and if so, what type of system is appropriate. Systems for heating buildings (and cooling them, if necessary) can be customized to meet most needs. Structures can also be designed to make use of passive solar heating.

Credits

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Lesson 1: Safety in Working with Concrete

Concrete is involved in nearly every type of construction project. Its benefits for construction ensure that it will continue to be popular in the future. Concrete does have a few specific hazards that are described in this lesson, but the potential for injury can be greatly minimized by following the suggestions given here.

What is Concrete?

Concrete is an artificial stone-like material consisting chiefly of sand, gravel, cement, and water. These materials are mixed together and harden and set due to a process called hydration, in which the cement combines with water and bonds to the different components. Concrete is a versatile construction material that can be adapted to almost any application and molded into many different shapes. It has a relatively low maintenance cost, is easily repaired and poured, and is easy to work. Figure 1.1 shows a list of some of the diverse uses of concrete.

Figure 1.1 - Uses of Concrete

Sidewalks	Roads	Brake linings
Foundations	Dams	Fence posts
Floors	Sewer pipes	Barges
Walls	Monuments	Canoes
Chimneys	Bridges	Caskets
Beams	Canals	Missile silos
Bricks	Bank vaults	Nuclear containment facilities

Dangers in Working with Concrete

A hazard encountered in concrete construction is tripping and falling. When preparing a site for concrete to be poured, rebar or wire is commonly staked and tied with wire at the site, creating a maze of wire and metal. Crossing this material only when necessary and taking care when doing so is the best way to avoid falling.

Working with concrete may involve different kinds of equipment that are potentially dangerous to other people. Tools such as power floats, which are gasoline-powered machines used to put a smooth surface on concrete, or mobile concrete shoots on trucks can kill a person if he or she is accidentally hit. Being alert at all times can help avoid accidents with equipment.

Burns caused by the chemicals in concrete are perhaps the most common injury when working with wet concrete. Concrete burns, which may involve large areas of the body, can be very severe; they consist of ulcerated areas where skin and flesh have been eroded away. These burns are extremely painful and require medical attention. The burns are caused by prolonged skin contact with some of the ingredients used to make cement. The amount of time before serious damage occurs will vary depending on the individual and situation. However, exposure of one hour or more will usually cause significant skin damage, and the length of time could be much less for someone with sensitive skin. By the time significant discomfort is felt, the skin has already been damaged, which often leads people to become careless since they do not realize they are injured until it is severe. Protective clothing and gear should always be used to prevent injury. Immediately flushing with water and washing an exposed area will likely prevent any effects.

If concrete is mixed on site, the cement in powder form has the same potential for injury as when it is mixed. Powdered cement may become airborne. This powder can be extremely irritating and damaging if it gets in the eyes or is inhaled, producing the same caustic results as exposure to wet cement. The use of proper protective gear minimizes this hazard.

Protective Clothing

The following items of clothing are of value in preventing injury. Workers should use protective eye gear, either goggles, which provide the best protection, or safety glasses, when working with cement in wet or powdered form. Disposable face masks are inexpensive and effective in reducing the amount inhaled when working with powdered cement. A long-sleeved shirt and heavy work pants will greatly reduce the amount of skin exposed. Waterproof or heavy work gloves will protect the hands from exposure; waterproof gloves are preferable. Finally, rubber boots will help protect the feet from exposure.

Summary

Agricultural structures usually involve concrete. Being aware of the hazards involved and following the safety suggestions given in this lesson will greatly reduce the risk involved. Protective clothing is particularly important in preventing injury.

Credits

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Lesson 2: Factors Affecting the Quality of Fresh Concrete

Concrete has many uses in the agricultural industry, from sidewalks to buildings. When looking at concrete, the question arises, "How is concrete made?" This lesson will explore the raw materials used in concrete, how to mix concrete, the additives used in concrete, and how to test concrete to see if it has the proper consistency.

The Components of Concrete

Concrete is a compound made from several different components. The main materials in concrete are aggregates, water, and cement.

Aggregates (sand and gravel) - Aggregates typically make up 60 to 80 percent of the volume of the concrete mixture. Aggregates are classified into two main categories. Fine aggregates are those particles that are smaller than a quarter inch in size; they can pass through a number four sieve, which is a sieve with four wires per inch. Fine aggregates are typically called sand. Coarse aggregates, called gravel, are particles larger than one quarter inch in size. The sand used in concrete should be clean and relatively dry, while the gravel should be clean and uniform in size. A larger aggregate size will result in stronger concrete and more economical costs.

Aggregates have several functions. They provide a cheap filler material that adds volume to the concrete. They are also stable materials that will resist forces on the concrete and that help to maintain volume while the concrete sets and hardens.

Occasionally other compounds besides sand and gravel are used as aggregates for speciality applications. Sometimes vermiculite and pearlite, compounds naturally found in the soil, are utilized when the concrete needs to be lightweight. The resulting concrete can be sawed. Clay, shale, and crushed brick can act as insulation. Steel and iron shot may be used as aggregates in the high density concrete for radiation shielding, as in a nuclear reactor or in the walls surrounding the x-ray laboratory in a hospital or clinic.

Water - Water is another important ingredient in concrete. Water serves several purposes in the concrete mixture. It allows the concrete to be molded or shaped, aids in mixing, and plays an important role in hydration, the chemical reaction between water and cement that bonds the mixture together.

The water used in concrete should be clean. If the water has too many impurities, the quality of the concrete will suffer. Generally, if the water is potable, or drinkable, it can be used in the concrete. The water should have less than 2,000 ppm (parts per million) of total dissolved solids.

Abram's Law is an accepted rule for concrete that describes the relationship between water and concrete. As stated in Ahren's *Concrete and Concrete Masonry*, the law is "For given materials and conditions of handling, the strength of concrete is determined primarily by the ratio of the weight of mixing water to the weight of cement as long as the mixture is plastic and workable." In other words, less water is generally better in mixing concrete, as long as the mixture is workable. Too much water weakens the final concrete mixture.

Cement - Cement and concrete are often referred to as if they are the same thing, but they are not. Cement is an important ingredient in concrete. With water, it forms the glue that holds the concrete together as it forms and hardens.

Portland cement is probably the most common cement used today. Portland cement was first patented in 1824 by a man named Joseph Aspdin.

The manufacturing of portland cement involves several steps. Limestone is the base material for cement. The limestone is taken from a quarry and crushed into a fine powder. This powdered limestone is then mixed with clay or shale, and the mixture is ground again. The ground mixture is sent to a kiln, or oven, to dry. The name of this dried product is clinker. After the clinker is removed and cooled, gypsum is added, and the mixture is ground one final time to produce portland cement. Table 2.1 gives the final chemical composition of portland cement.

Five types of portland cement are commonly produced and used for different applications. Type I is for common applications. Type II is used where heat buildup is a concern, as in a thick wall or large structure. Type III, or high early strength cement, is useful when the concrete needs strength in the first two to three days after pouring.

Table 2.1 - Cement Composition

Material	Percentage (%)
Lime	60-66
Silica	19-25
Alumina	3-8
Iron	1-5
Magnesia	0-5
Sulfur trioxide	1-3

as in a driveway or walkway for a building. Type IV, or low heat cement, reduces the heat generated by hydration; it is used in confined indoor spaces. Type V, also known as sulfate resistant cement, is necessary when the concrete is poured over alkaline soils, which can decrease the durability of the concrete.

Two agencies regulate portland cement and its specifications. They are the American Society for Testing and Materials (ASTM) and the Canadian Standards Association (CSA). These agencies determine the requirements for the different categories of portland cement and work to maintain concrete quality.

Mixing Concrete

The most common agricultural mixes are usually described in one of three different ways. These descriptions are useful in ordering and preparing the mixture. The first method of describing concrete mixtures refers to the number of bags of cement in each cubic yard of concrete, which is equal to 27 cubic feet of volume. Ready-mix concrete ordered through a supplier is usually ordered using this method. The three most common ready mixes and their applications are shown in Table 2.2.

A second method of referring to concrete mixes uses a ratio that shows the relative amounts of the different components of the concrete. A common mixture is 1:2:3-6. This ratio indicates that the concrete is one part cement, two parts sand, three parts gravel, and six parts water. Each part consists of a particular volume, such as one cubic foot.

The third method used to describe concrete mixes indicates the gallons of water mixed with each sack of cement. Common mixes described in this manner are 5.0, 6.0, and 7.0. In their uses, these mixes correspond to the various ready mixes already discussed, as indicated in Table 2.2. To learn the amounts of other components needed to make the cement, specific charts must be consulted to find the volume of each ingredient in a cubic yard. These charts may be available in reference books about concrete.

Concrete Additives

Sometimes circumstances may call for a particular type of concrete. For that reason, certain additives, called admixtures, are mixed into the concrete to give it special characteristics. Concrete additives fall into six main categories: air entraining additives, superplasticizers, retarding additives, accelerating additives, mineral additives, fibers, and pigments.

Air entraining - Air entraining additives force small air pockets in the concrete. The process of trapping air in the concrete is called air entraining. Large air pockets can weaken the concrete, but small pockets are beneficial in several ways. Air entraining improves concrete's workability, water tightness, and finish qualities. It also increases the concrete's resistance to freezing and thawing and its resistance to salt and sulfates, which can erode the concrete. Concrete with these small air pockets is called air-entrained concrete.

Table 2.2 - Common Mixes

Mix	Applications
5 bags of cement/yard, or 7 gallons of water/sack of cement	Foundation walls, footings
6 bags of cement/yard, or 6 gallons of water/sack of cement	House floors, dairy floors, driveways, septic tanks
7 bags of cement/yard, or 5 gallons of water/sack of cement	Concrete under severe conditions, concrete exposed to acids or severe weather

Superplasticizers - These additives increase the strength of the concrete by altering it so that it needs less water to be workable.

Retarding - Retarding additives slow down the setting process, resulting in greater long-term strength.

Accelerating - This type of additive speeds up the setting of the concrete, resulting in more early strength and making the concrete less vulnerable to temperature changes during setting. They are frequently used in cold weather to force the concrete to set more quickly. One of the more common additives used today is an accelerating additive, calcium chloride.

Mineral - Mineral additives increase the strength of the concrete.

Fibers - Fibers reduce the tendency of the concrete to break along seams or at the edges. The fibers do not truly increase the strength of the concrete but help to bind the concrete together.

Pigments - Pigments change the color of the concrete. Adding certain minerals to the whole batch of concrete or only to the final layer can change the color of the concrete. Table 2.3 lists the minerals added to concrete to produce various colors.

Table 2.3 - Concrete Pigment Additives

Color	Additive
Blue	Cobalt oxide
Brown	Brown iron oxide
Buff	Synthetic iron oxide
Green	Chromium oxide
Red	Red iron oxide
Gray	Black iron oxide or carbon black

Other than calcium chloride, most additives are not commonly sold in hardware stores but are carried by local ready-mix suppliers. They can be mixed into the concrete to meet the specific needs of the project.

Slump Tests

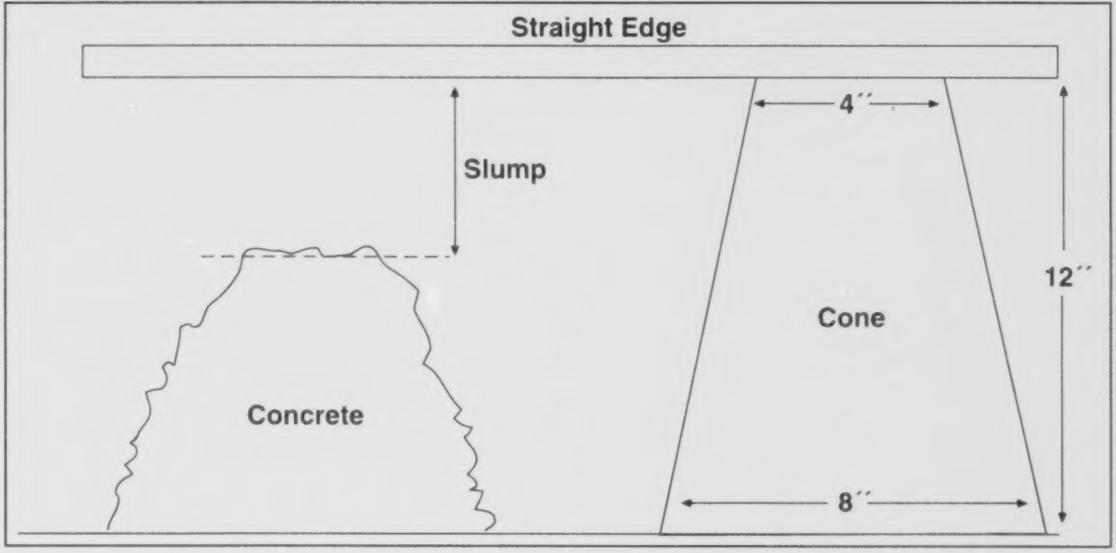
Mixing concrete is not like cooking from a recipe, because some ingredients may already contain a certain moisture content. In mixing concrete, adding the right amount of water is important. The amount added to the mix should be decreased if the aggregates are already moist, or the concrete will be too wet. A slump test determines if the concrete is of the proper consistency; it indicates if more or less moisture is needed. The slump test is important because the test makes it possible to prepare a concrete mixture with the optimal combination of strength and workability. This test is the final step prior to pouring the concrete.

The procedure for performing the slump test is relatively simple. The test involves the use of a metal cone that is 12 inches tall, with a diameter of 4 inches at the top and 8 inches at the bottom, and open at both ends. It is placed on a flat surface with the wide end down. Prior to being filled with concrete, the cone may be moistened with oil to make cleanup easier. The cone is first filled one-third full with concrete. The concrete is tamped down with a 12-inch metal rod 25-five times to make it settle and remove any air pockets. Concrete is then added until the cone is two-thirds full, and the concrete is tamped again. Finally, the cone is filled, and the concrete is tamped for the third time. The cone is then carefully removed, and the concrete "slumps," or drops in height due to gravity.

After the concrete has stopped decreasing in height, the slump is measured. A straight edge is placed across the top of the cone, and a measurement is taken from the straight edge down to the average level of the top of the concrete, as shown in Figure 2.1. Usually, the slump should be between 1 and 3 inches. Too much slump indicates too much water, while not enough slump indicates a lack of water. If too much water is present, adding aggregates or cement will thicken the mixture.

Adding ingredients should be the last resort in mixing concrete because it will result in weaker concrete. Ideally, the correct amounts of ingredients are used the first time. Also, most state or federal construction contracts prohibit adding ingredients after the initial mix. If the mix is not correct when it reaches the work site, the entire batch is rejected.

Figure 2.1 - Measuring Slump



Summary

Concrete is a mixture of cement, aggregates (sand and gravel), and water. The relative amounts of these ingredients in the mixture depend upon the use of the concrete. Concrete mixes are described in terms of the bags of cement per yard; the ratio of cement, sand, gravel, and water; and the gallons of water per sack of cement. The seven classes of common concrete additives are air entraining additives, superplasticizers, retarding additives, accelerating additives, mineral mixtures, fibers, and pigments. A slump test is necessary to determine the proper amount of water for the concrete mixture.

Credits

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Lesson 3: Site Preparation

In any situation where a building is being constructed, the building site needs to be prepared to make future steps of construction more efficient. A number of factors affect the final quality of a building site. The process of site preparation addresses these factors.

Preparing a Subgrade

Once a site has been selected, it needs to be prepared for construction. This process begins with preparing the subgrade, which is a surface leveled off in preparation for laying a foundation. The subgrade will be slightly bigger than the foundation. The steps in forming a subgrade are important for the rest of the construction process and so should be followed closely.

Drainage - If the construction site does not drain well, installing a drainage system below the site to remove excess water may be necessary. If the system is needed, installation is much easier before any construction occurs. A drainage system typically consists of a series of underground pipes that collect excess water and direct it away from the site. Systems are usually installed by a licensed business on a contract basis.

Removal of topsoil - In some cases, the topsoil is scraped off the site with a tractor and blade prior to other excavation. The topsoil may be saved for later use, especially for landscaping the property. If the topsoil is not used for landscaping, it can be sold, since many people buy good quality topsoil for use around their homes.

Removal of organic material - Organic material consists of matter produced by plants and animals that is found in or on the soil. The organic material on the building site needs to be removed as much as possible. This material does not readily mix with concrete and can even have a slightly oily surface, which further prevents mixing. The particles in the concrete cause inclusions, or holes created when the matter eventually decays, that will weaken the overall strength of the concrete. Also, organic material will keep the ground from being packed tightly to support the weight of the structure, and as the material decays, settling will occur. Organic material is typically removed with a tractor and blade.

Removal of rocks and stones - In addition to topsoil and organic material, larger rocks and stones should be removed, since they may cause major differences in the slope of the land. They can be removed using a tractor and blade. These rocks can be placed in lower areas, as well as areas with poor drainage.

Subgrade slope - After the removal of topsoil, organic material, rocks, stones, and trash, the site should be graded using a tractor and blade to create a desired slope for drainage purposes. Typically, a 3 percent slope away from the building is considered minimal.

Packing or compacting - Once the site has the proper slope, the soil needs to be packed. Driving a tractor back and forth across the site so that the tires form a pattern across the previous tire tracks will pack the soil down. Portable, hand-operated packers are also available. Packing is commonly done using a sheep foot roller to compact the soil. Packing prevents differential settling of the soil, in which some areas settle more than others because of soil compaction due to the weight of the concrete.

Sand or aggregate fill - Most construction sites use fill, which consists of added sand or aggregates, to create a level site and leave a more uniform surface under the concrete foundation. If the soil texture and structure (the shape of the particles the soil normally forms) do not permit proper soil drainage, placing 4 to 6 inches of sand or aggregate on the site will enhance drainage by allowing water to flow downward more readily. If fill is added, the site should be packed again after the fill is in place.

Vapor barrier and insulation - If a drainage system cannot be used or if excessive soil moisture is a continual problem, a vapor barrier or retarder should be used under the concrete. The vapor barrier, which is typically polyethylene sheeting, prevents moisture from being absorbed into the concrete. In cold climates, insulation is also commonly placed under the concrete to maintain heat in the building and keep the floor warmer.

Dampening the site - If a vapor barrier is not used and the ground is dry, the site should be sprayed with water to dampen the fill. This practice will prevent excessively dry fill from pulling water out of the concrete during the curing process. If the ground is relatively moist already, dampening the site is not necessary.

Footings

Once the subgrade is prepared, construction of the building can begin. The first step in constructing a building is to construct the lowest part of the building, the footings. Footings, as shown in Figure 3.1, are large supporting blocks of concrete between the foundation and the soil. They are normally placed around the exterior edge of the building and under walls that will support the structure's weight. The footings spread the weight of the building across a larger area and make the structure more stable. Footings are usually poured on site but can be poured at another location and later placed at the site. They are necessary for several different reasons, including temperature, moisture, and soil structure, all of which can affect the foundation of the building.

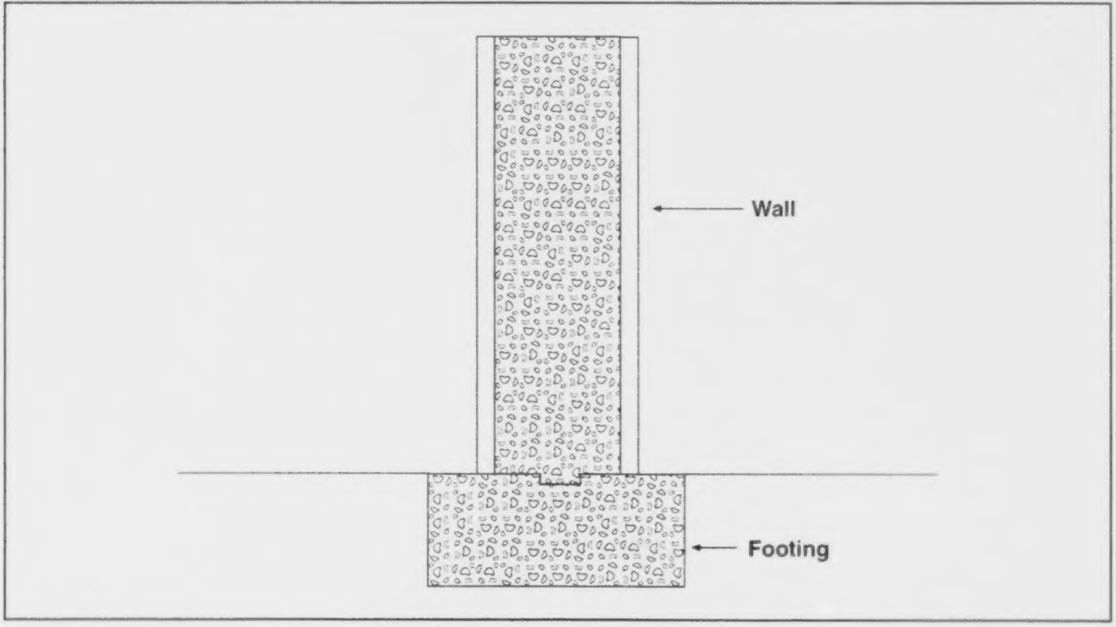
The frost line is the deepest point in the soil where frost is normally found during the winter. Footings located below the frost line will decrease, if not eliminate, movement of the building due to expansion and contraction of the soil because of temperature changes. To place the footings below the frost line, the building site must be excavated to the proper depth. Variable levels of moisture during the year will cause the soil to expand and contract as well. The building can be stabilized by placing large footings on a sand or aggregate base.

Soil structure can affect the use of footings. Soils with a very loose soil structure tend to allow more settling of the building over time. This settling can be diminished by integrating larger than normal footings. Also, certain clay soils expand and contract dramatically when wet. Placing footings on a layer of sand and aggregate can reduce the movement of the building due to these changes.

Laying Out the Building

Footings need to be placed carefully, since they will determine whether the building is placed squarely in the correct location. The first step in laying out a building is driving stakes into the ground where the corners of the structure are to be located. If an addition to an existing building is planned, the two corner stakes should be placed in relation to the building by measuring the desired distance from the building and the distance between the stakes. For a new structure, a stake is driven to mark the location of a corner, and measurements are made to the adjacent corners. After stakes are placed at these corners, measurements can be made from them to

Figure 3.1 - Footing



determine the placement of the final stake. The measurements between the stakes should be made carefully so the building is exactly the size desired. After all the corner stakes are in place, strong twine or rope is tied between them to represent the sides of the building.

To determine if the stakes are square on all four corners of the building, diagonal measurements should be made from the corner stakes. When the measurements are identical, the building is square, as illustrated in Figure 3.2. If the building's diagonals are not equal, the stakes must be carefully moved. For example, if diagonal A was longer than diagonal B, as in the second diagram in Figure 3.2, stakes 1 and 2 would be moved to the left until the diagonal measurements are identical. Because of the twine connecting the stakes, the building's dimensions remain correct.

The corner stakes are where the forms will be placed for pouring the footings, so a method is needed to indicate the corners when the stakes are removed. The procedure for marking the corners involves the use of batter boards, which are shown in Figure 3.3. Batter boards are typically either 1" × 4" or 1" × 6" boards nailed to three 2" × 4" stakes at least four feet from the corner of the building. If the twine connecting the stakes is extended to the batter boards, the corner stakes can be removed because the intersection of the strings still marks the location of the corner of the building. Suspending a weight like a plumb bob from where the strings intersect at the corners will ensure that the strings cross exactly at the corner of the building. After the lines are in place, the position of the lines is marked, and a saw kerf about ¼" deep is sawn into the board to indicate the proper placement. The lines can then be removed and replaced if necessary. When the position of the lines is marked, the stakes can be safely removed. Forms, which will be discussed in greater detail in the next lesson, can then be placed under the string in preparation for pouring the footings.

Preparing the Final Grade

After the footings have been placed and soil is added around them to create a level surface, the final preparation of the site can be done. Preparing the final grade is the last step prior to pouring the concrete. For the final grade, more care should be given to the slope and fill on the site.

Figure 3.2 Equal and Unequal Diagonals

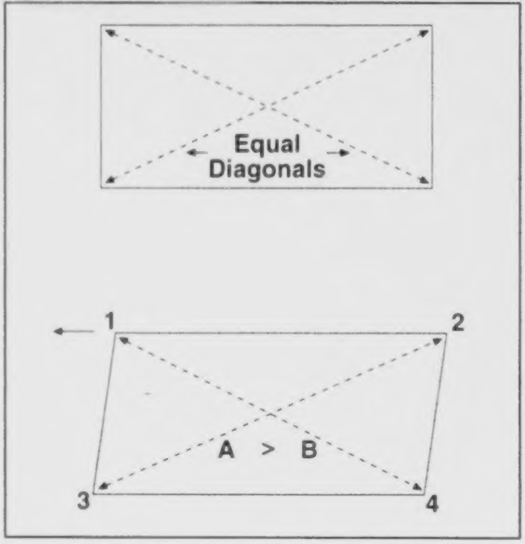
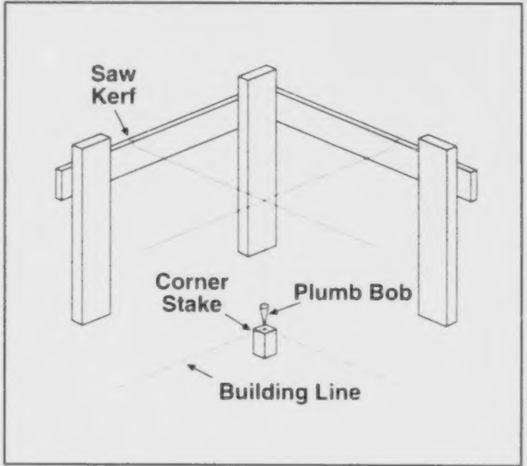


Figure 3.3 - Batter Boards



The final slope of the building site can greatly influence the amount of concrete needed and the degree to which the forms that will hold the concrete will need to be leveled. To determine the slope of the building site, several different methods can be used. A hand-held level can offer reasonably accurate readings for the site. To increase accuracy, a tripod-mounted transit or level should be used. This tool will provide much more accurate readings indicating the amount of soil to be removed, or cut, or the amount of fill added to various locations on the site.

Once the exact location of the building has been determined, fill needs to be added across the site to maintain the desired slope. Fill is especially important if major depressions or high spots are found on the building site. Hopefully the initial work with a tractor and blade has made the location nearly level, but often fill is needed to make the entire site level. Low wet spots can be filled with aggregate or rocks.

Equipment Needed

The tools used in site preparation are not specialized. However, they make site preparation easier and more accurate. The tools needed to prepare a building site include a tractor with a blade, a compactor or packer for the soil, shovels, and a transit or level with a surveying rod and the tripod for the transit or level.

Summary

Site preparation is a very important step in building construction. The subgrade and final grade should be prepared properly to provide a good base for the foundation. Footings should be planned to support the structure, which needs to be laid out carefully to make sure that it is square. Proper site preparation will make the rest of the steps in building construction easier to accomplish and result in a higher quality finished product.

Credits

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Lesson 4: Pouring a Concrete Slab

One of the most common activities in pouring concrete is pouring a concrete slab. Concrete slabs are used in foundations, garage floors, sidewalks, and many other places. This lesson will examine the procedures used in pouring concrete slabs.

Tools for Pouring Concrete

As with any construction task, specific tools and equipment are needed to pour a concrete slab. The tools required include sledge and claw hammers, a carpenter's level, a shovel, a hose and water source to moisten the site, a tape measure, a transit or a surveyor's level used with a surveying tripod and surveyor's rod, a calculator for any calculations that may need to be made, a circular saw, a carpenter's or framing square, and lumber and 16d duplex-head nails for the forms.

Forms

Once this equipment has been obtained, construction can begin on the forms for pouring the concrete. Forms are structures designed to hold the concrete in the proper shape and location until it sets and hardens. Forms can be constructed of different materials, such as wood, aluminum or metal alloys, and earth.

Wood forms for pouring a sidewalk or slab are usually made of 2" × 4" or 2" × 6" boards. The wood should be free of knots and decay, which will weaken the form. Wood forms are usually coated with a lightweight oil to prevent the concrete from sticking to the form. If plywood is used, SP plywood, or plyform, should be utilized; it is a special plywood made with a waterproof glue that repels the moisture in the concrete so the concrete will not be dried out by the forms. Hardboard, a wood composite sometimes called Masonite, is sometimes used when forming curves because of its strength and flexibility. Wood forms are easy to construct and are relatively inexpensive.

Aluminum or metal alloy forms will give a smoother, more uniform finish to the concrete. These forms are structurally stronger than wood forms. They will yield extremely straight, square concrete, since the forms do not bend or sway under the weight of the concrete like wood forms will. Aluminum or metal alloy forms are expensive to purchase and cannot be easily constructed like wood forms.

Earthen forms can be constructed by shoveling soil in a pile in the desired location. The earth is covered with a plastic lining to prevent soil from mixing with the concrete and to keep moisture from bleeding out of the concrete into the soil. Earthen forms are rarely used and result in a poor quality slab.

Constructing Forms

Once a type of form has been chosen, forms can be purchased or made. This section of the lesson will describe the construction of wood forms because they are the most commonly used type.

The first step in constructing forms is determining the desired height of the forms. For a 4-inch slab, which is a common size, 2" × 4" boards are used. However, if the board has been planed or smoothed, the end product is only 1½" × 3½". This board size can be used for forming a 4-inch slab if soil has been placed on the outside of the form to strengthen it and close the opening at the bottom. If thicker slabs are desirable, wider boards, such as 6-inch or 8-inch boards, are required for the sides of the forms.

The edges of the boards are put in place directly underneath the string or twine used when laying out the corners of the slab, as described in the last lesson. Small stakes should be driven at least 6 inches into the ground with a hammer every 4 feet along the outside of the boards to stabilize them and hold them in place. The tops of the stakes must be below the edge of the form to allow the slab to be worked as the concrete dries. If the stakes are above the edge, they will interfere with leveling the concrete. If necessary, the tops of the stakes can be cut level with the form using a circular saw. The stakes are nailed to the boards using duplex-head nails attached on the outside of the forms. This type of nail makes the removal of the nails easier when the forms are taken apart after the concrete sets.

Once the outside edges of the forms are in place, the forms should be checked to ensure that they are square. A tape measure can be used to check whether the diagonals are equal. If they are not, the forms should be adjusted until they are square.

Once the forms are square, a carpenter's level or the transit with its tripod and surveyor's rod should be used to determine if the forms are level. If they are not level, a hammer can be used on the higher spots of the form to decrease its height. At this point, whether the slab should slope or be level should be considered. If water or manure drainage is a concern, the slab should have at least a 4 percent slope in the direction that the excess water or manure should run off. This slope should be figured into the final placement of the forms.

If the slab is to curve, plywood can be used in place of boards to make the forms. The plywood should be cut so the grain of the plywood runs vertically because the stress from the concrete would crack or break the form if the grain ran horizontally. The stakes should be placed only 1 to 2 feet apart on curves instead of every 4 feet. Curves place more stress on the form, and more stakes are necessary to keep the forms in place.

Forms should be secured tightly at the corners to prevent them from separating. Sometimes corners are attached using bolts or screws, which are stronger than nails.

The Purposes of Reinforcement in Concrete

Concrete must often be reinforced to make it stronger and prevent various types of damage. Reinforcement can strengthen the concrete and help it to resist the forces acting on it. Concrete by nature has great compressive strength, which is the strength to resist forces pressing downward on the concrete. However, concrete does not have good tensile strength, which is the ability to withstand tension or pull. For example, a heavy weight, like a tractor, close to the edge of a slab might cause the concrete to crack or break because of the tension on the concrete at the edge. Reinforcing the concrete will increase its tensile strength, especially at the edge of the slab. Reinforcement will also reduce the tendency of the concrete to crack due to changes in temperature.

Types of Reinforcement

The most common types of reinforcement are made of steel. Steel has high tensile strength, which helps resist the forces acting on the concrete. To be effective, the steel used in concrete for reinforcement must be clean and free of rust and organic debris like leaves. In some cases, specially manufactured fibers can be added to the concrete as reinforcement in place of structural steel.

Steel rods are also commonly known as reinforcing bars, or rebar. Rebar can be purchased in a variety of sizes, from ¼ inch up to 2 inches in diameter. These rods are typically sold in lengths of 20 feet and are cut to fit. Steel rods are identified by a number, such as 2, 3, 4, 5, or 6. These numbers refer to the diameter of the rod, expressed in eighths of an inch. Number 4 rebar is ½ inch in diameter.

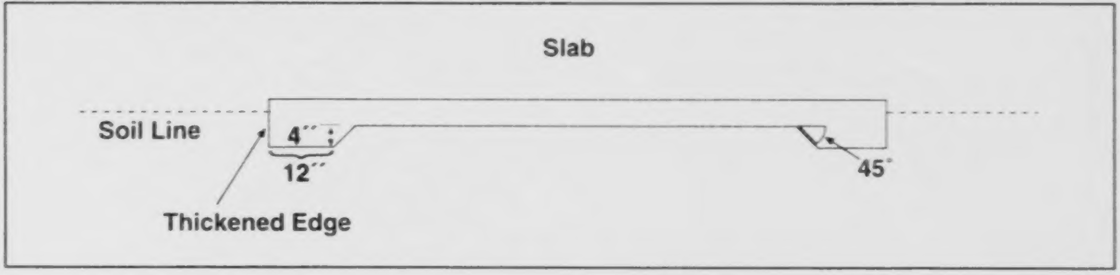
The other common type of reinforcement is steel wire mesh. Wire mesh consists of rods of steel wire joined in a crisscross pattern to form a mesh. The steel comes in a number of different diameters, ranging from 0000, which is thin, up to 16 gauge. Meshes also differ in the spacing between the wire rods in the mesh. Common spacings are 2, 3, 4, 6, 8, 10, 12, and 16 inches. Rolls of wire mesh are commonly sold in widths of 36, 42, 48, and 60 inches. Common lengths are 150, 200, and 300 feet.

Installing Reinforcement

Steel reinforcement should be placed in the bottom half of the slab, where the tensile forces on the concrete are the greatest. The reinforcement is placed approximately 1 inch above the soil or fill by wiring it to 12-inch rebar stakes that have been driven into the ground. Both rods and wire mesh need to be joined where they meet. Rebar should overlap by a length that is equal to 24 times the diameter of the rod and not less than 12 inches, while mesh should be overlapped one full square spacing plus 2 inches. The reinforcement should be tied with thin wire where the bars or wire mesh meet. When installing steel reinforcement, be sure to place the rebar or mesh around the outside edges of the slab. However, the ends of the reinforcement should be placed at least 3 inches from the very edge of the slab, so that it does not eventually stick out of the edge of the concrete and pose a hazard. After the rebar or mesh is in place, concrete is poured on top of the reinforcement.

Sometimes the edges of the concrete are thickened to provide additional reinforcement for the rebar. Thickened edges involve placing a thicker, deeper layer of concrete at the edges of a concrete slab as a type of footing. The edge

Figure 4.1 - Thickened Edges for Reinforcement



should be 4 to 6 inches thicker than the slab itself. The base of the thickened area should be 12 inches wide, with a 45-degree slope from the bottom of the main slab to the bottom of the thickened edge, as shown in Figure 4.1. This type of reinforcement is used on the perimeter of feeding floors and driveway edges where livestock or vehicles enter the paved area.

Expansion and Control Joints

Larger slabs of concrete like a concrete pad or sidewalk will at times move for various reasons, such as settling or pressure. A way to reduce the cracking of the concrete that results is to use expansion and control joints. Expansion and control joints may either be grooves made in the concrete or material placed in the concrete to prevent breaks or control where the concrete breaks. Joints can often prevent breakage, but if the concrete does break, these devices will also limit the location and force the break to form a straight line. The straight grooves commonly seen across sidewalks and driveways are expansion and control joints.

Expansion and control joints can be made using several different methods. For joints consisting of grooves in the concrete, a piece of angle iron, which is L-shaped, or a V-shaped piece of wood can be pushed in a straight line through the drying concrete. A mason's trowel can also be used to inscribe a groove into the drying concrete. Another method is to saw grooves in the concrete. These joints are cut into the dried concrete with a masonry saw 4 to 12 hours after the concrete is poured. The depth of the groove created using each of these methods will be less than one inch. An alternative method of installing expansion and control joints is to place small strips of IKO board on edge in the form before the concrete is poured. IKO board is soft and spongy and is sometimes used to make bulletin boards. The board will expand and contract as the concrete dries and shrinks or moves due to expansion and contraction. Both of these types of control joints may be used in some situations.

Expansion and control joints should always be placed in straight lines perpendicular to each other in the concrete slab. The joints should make squares in the concrete and can be formed using a framing square. For slabs 4 inches thick or less, joints should be made in the concrete every 10 feet. For slabs 6 inches thick, joints should be included every 15 feet.

Summary

Pouring a concrete slab is a common task when working with concrete. Knowing the proper tools to use, the proper methods of forming and reinforcing concrete, and how to control expansion and breakage will result in a higher quality finished product.

Credits

Ahrens, Donald L. *Concrete and Concrete Masonry*. St. Paul, Minn.: Hobar Publications, 1976.

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Lesson 5: Ordering, Pouring, and Finishing Concrete

After preparing the forms for a concrete slab, the next step is pouring the concrete. Before the concrete can be poured, however, it must be ordered and mixed.

Calculating the Concrete Quantity Needed

Once the forms are ready, the process of pouring the concrete can begin. In instances where the volume of concrete being poured is larger than one yard, most people will order the concrete from a ready-mix plant and have it delivered to the site. This practice eliminates the need for obtaining the materials and equipment to mix the concrete on site. If the concrete is purchased from a ready-mix contractor, an order for the amount of concrete needed must first be calculated.

Concrete from a ready-mix plant is ordered in cubic yards, which is the standard volume used when working with concrete; one cubic yard is equal to 27 cubic feet. Plants typically sell the concrete at $50 to $70 per cubic yard plus a delivery charge. Since concrete is somewhat expensive, care must be taken to accurately determine how much is necessary. Once the concrete arrives, all of it must be used, or it becomes waste.

To calculate the number of cubic yards needed when pouring concrete for a rectangular slab, multiply the length, width, and depth in feet of the slab, and divide this number by 27, as shown in Figure 5.1.

Using this equation, 3.56 cubic yards are required for a slab that is 12 feet by 16 feet by 6 inches (12 × 16 × .5, divided by 27). If this were the only concrete poured that particular day, 4 yards of concrete would be ordered, since most ready-mix plants sell only whole yards of concrete.

If the slab to be poured is circular, the formula for the volume of a circle is used to calculate the amount of concrete needed, as illustrated in Figure 5.2.

A concrete slab 4 inches thick under a grain silo that is 24 feet in diameter would require 5.53 cubic yards of concrete (3.14 × 12 × 12 × .33, divided by 27).

When ordering concrete, the amount ordered will usually be more than the amount calculated by a factor of 10 to 25 percent. The amount needed is multiplied by 1.1 or 1.25 to provide the extra concrete. This additional material will make up for any spilled concrete and differences in soil or fill level, especially for low spots.

Factors to Consider When Ordering Concrete

When deciding to order concrete, several issues need to be addressed. Factors to consider include the weather, conditions affecting the type of concrete needed, labor needs and availability, access to the area by truck, and water needs.

The weather should be considered when ordering concrete. Concrete should preferably not be poured in a rain storm or when temperatures are below 40 degrees or above 85 degrees. These weather conditions will affect the rate of curing, or hardening, of the concrete as well as the overall final strength of the concrete. If concrete must be poured in cold weather, calcium chloride has to be added to the mix.

Certain conditions may affect the type of cement ordered. The concrete mix may include different types of portland cement depending on different conditions. For example, if the concrete is to be poured on alkaline soils or in areas where heat may build up, a particular type of concrete mix is used. Other mixes are required if the concrete

Figure 5.1 - Formula for Rectangular Slab

$$\text{Length (ft.)} \times \text{Width (ft.)} \times \text{Depth (ft.)} \times \frac{\text{yd.}^3}{27\ \text{ft.}^3} = \text{Cubic yards of concrete}$$

Figure 5.2 - Formula for Circular Slab

$$\pi\ (3.14) \times \text{Radius}^2\ (\text{ft.}^2) \times \text{Depth (ft.)} \times \frac{\text{yd.}^3}{27\ \text{ft.}^3} = \text{Cubic yards of concrete}$$

needs strength in the first two to three days or if the heat generated by the concrete needs to be reduced, as for large water dams.

Labor needs and availability should also be considered. Pouring and finishing concrete is not a one-person job. The arrival of the delivery truck should be timed to occur when sufficient labor will be available to pour and finish the concrete.

Another factor to consider is the access and elevation of the delivery truck. Most ready-mix businesses offer trucks with extension slides to allow the concrete to be poured over greater distances and avoid hauling the concrete in wheelbarrows. Companies generally also have a few trucks that can pump the concrete to a location higher than the tires of the truck.

Water needs are another consideration. Water is important in the process of pouring concrete. The site needs to be sprayed with water if the fill is dry. The concrete is sprinkled with water as it cures to increase the moisture content and improve the strength of the finished concrete. Water will also be used to clean all the equipment.

Pouring a Slab

After the desired amount of concrete has been determined, ordered, and delivered, the concrete is poured. The process of pouring concrete has several steps that need to be followed closely.

Before the concrete can be poured into the forms to cover the reinforcement, the site needs to be moistened. This task needs to be done while the concrete is being delivered or mixed on site.

The concrete should be poured as soon as possible after its arrival at the site or after being mixed. This procedure will maximize the amount of moisture in the concrete, increasing its strength. Pouring it right away will also aid in maintaining the proper slump, or the correct moisture level of the concrete.

An important point to remember is that concrete begins to set 30 to 60 minutes after pouring. If the concrete is moved in any way during the first hour after pouring, its strength is reduced. For this reason, the truck or mixer should be moved as close as possible to the final location of the concrete to avoid having to move the concrete in wheelbarrows.

When unloading the concrete from the truck, the chute or discharge tube should be placed as close to the ground as possible. If the chute is too high, the impact of the concrete hitting the ground will partially separate the aggregate from the cement mixture.

As the concrete fills the forms, a shovel or spade should be pushed through it, especially at the edges of the forms. The aggregate will then be well mixed and moved away from the edges somewhat, resulting in a smoother finish at the edge. Working through the concrete will also remove any air bubbles that may have resulted from pouring, giving the concrete more strength.

If the slab to be poured is wider than 10 feet, pouring the slab in two or more sections should be considered. Slabs wider than 10 feet will be more difficult to finish, since most concrete finishing tools do not have handles long enough to reach the entire area.

Concrete Finishes

Finishing is the process of working the surface of concrete to give it texture. Concrete can be finished using several different methods, which will result in different textures on the exposed surface. The finish selected will depend on the final use of the concrete. One type of finish creates a smooth surface, which is used where ease of cleaning is required, as for floors in a shop, house, or grain bin. Another method of finishing concrete provides a rough surface, which is used for traction on sidewalks, livestock walkways, inclined walks, and steps. A third type of finish is an aggregate finish, which is used for traction and decorative purposes and consists of exposed rocks on the surface of the concrete; it may be used anywhere a decorative surface is desired, such as sidewalks.

Finishing the Concrete

As one crew is pouring concrete, another crew can begin the finishing process after the concrete has begun to harden and its surface starts to dry out. The finishing crew will work the concrete to provide a flat, even surface that will be attractive as a finished product. They will also give the concrete the proper texture. Each type of finish requires a different procedure.

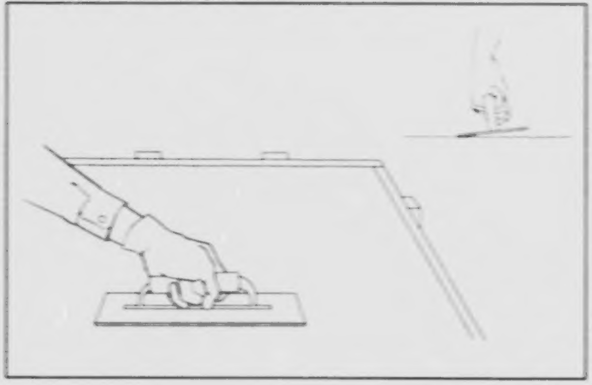
For a smooth surface finish, the first step is to screed the concrete. Screeding involves moving a board across the concrete along the top of the forms. This process will move concrete into lower spots inside the form and remove excess concrete. Screeding is typically done by moving a straight 2" × 4" board back and forth at a 90-degree angle to the edge of the form.

After the concrete has been screeded, a bull float is used to work the aggregate below the surface. A bull float is a wide board or flat piece of aluminum that is held level with the surface and tipped up slightly along the front edge as it moves across the concrete. The float will force the aggregate below the surface, leaving the concrete relatively smooth. Unfortunately, it also leaves small ridges in the concrete.

These small ridges are then removed using a power trowel, a steel hand trowel, or a magnesium hand float, which is similar to but slightly longer than the steel trowel and gives a smoother final surface. If the person pouring the concrete has access to a power trowel, it should be used. The power trowel is worked in a circular pattern to smooth away any edges, leaving a very smooth surface overall. If a power trowel is not available, a steel hand trowel can be used to achieve the same effect. The hand trowel or a magnesium float should be worked using a curving motion similar to the movement of windshield wipers on a car, with the edge of the tool sloping slightly upward as it is moved across the concrete to help compact the surface. Troweling is illustrated in Figure 5.3.

An edger should be used along the forms as the concrete begins to set to separate it from the forms and leave a slightly rounded edge, as shown in Figure 5.4. At the same time, expansion and control joints should be applied if they are needed.

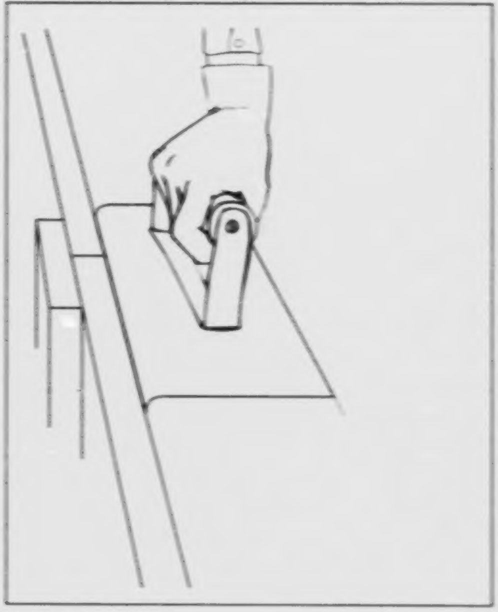
Figure 5.3 - Troweling Concrete



The process is similar for a rough surface finish. The concrete is screeded to even out the surface of the concrete, and a bull float is used to force the aggregate down. The ridges are removed using a power or hand trowel. The final step in rough surface finishing involves pulling a push broom across the surface of the curing concrete. The bristles will leave small, even grooves in the concrete that will reduce slippage and increase traction, especially when water freezes on the surface. An edger is used along the forms, and expansion and control joints are then applied.

An exposed aggregate finish creates a pebbly or rocky surface that is not smooth at all. For this type of finish, the concrete is again screeded and worked with a bull float. It is then lightly worked with the power or steel trowel, with less concern for creating a smooth surface. To add the aggregate to the finish, a layer consisting only of aggregate is applied evenly over the surface of the concrete. This layer is embedded using a board similar to the screed to force the aggregate into the concrete to a depth of about one half of its diameter. The aggregate should not be forced too far into the concrete, because the desired finish will be reduced. The concrete is then allowed to dry until surface water disappears. After the water has evaporated and the mixture can support a person's weight, a hose and bristle broom are used to remove any film of concrete on the surface of the exposed aggregate.

Figure 5.4 - Using an Edger



Summary

Ordering concrete for a specific job requires accurate calculations to determine the correct amounts needed. Factors such as the weather, conditions affecting the type of concrete needed, labor needs, access to the area, and availability of water should be considered. Once the concrete has arrived, efforts should be made to pour the concrete as soon as possible using the proper process. After the concrete starts to harden, it must be finished to meet the needs of the situation. If the concrete is poured and finished well, the result is high-quality concrete that will last for many years.

Credits

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Boyd, James S., and Carl L. Reynolds. *Practical Farm Buildings*. 3rd. ed. Danville, Ill.: Interstate Publishers, 1993.

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Lesson 6: Curing Concrete

Once concrete has been poured, the curing process begins to take place. While it may seem that the concrete is merely drying, a chemical process called hydration is in action. Curing is necessary because this chemical process gives concrete its strength. If it does not cure properly, the result is substandard concrete.

The Process of Concrete Curing

After concrete has been poured into forms and exposed to the air, it begins to harden in a process called curing. Most people think that concrete hardens because of evaporation or drying, but they are not correct. If concrete were to simply dry out, nothing would hold it together, and the materials would separate out. The curing of the concrete is the result of hydration, which is the mixing of a compound with water.

The curing process involves a chemical reaction between water and the elements in Portland cement. As the cement starts to react with the water, a substance called a gel is formed from the chemicals in the cement and water. The gel has a consistency similar to gelatin. Eventually the gel becomes a solid mass, thickening and hardening the concrete.

The rate of curing for pure concrete without additives is affected by temperature. The ideal temperatures for curing are between 65 and 75 degrees Fahrenheit. Temperatures higher than 75 degrees will cause the concrete to cure too quickly by creating excess evaporation; the concrete will then lose strength. In temperatures between 32 and 65 degrees Fahrenheit, concrete will cure, but the process will be slower. At temperatures below 32 degrees, the concrete will not cure. If concrete freezes during curing, permanent damage will occur.

The length of time that pure concrete is allowed to cure depends on the outside temperature. Generally, if air and soil temperatures are above 70 degrees Fahrenheit, the concrete should be allowed to cure for at least five days. If temperatures are 50 to 70 degrees Fahrenheit, the concrete should be allowed to cure for at least seven days. If the temperature is less than 50 degrees Fahrenheit, the concrete should cure for at least seven to ten days, and preferably longer. In all cases, the ideal curing time is 28 days, because the process continues until about that time.

No extra weight should be placed on the concrete during curing because it will stop the curing process. Keeping weight off the concrete will also increase its final strength. Construction of the structure should wait until the concrete has completely cured.

Determining if the concrete has cured completely is difficult. The outside layer or shell of the concrete will cure first, with the inside curing last. No direct method exists for determining if the concrete on the inside has cured. The outside is cured when the concrete becomes light gray in color.

The Importance of Curing

Curing is important because it causes the concrete to harden and determines its strength. To a point, the more water the concrete can retain, the greater its strength will be. For maximum strength, the concrete must have adequate water to continue the chemical reaction until it has completely hardened. Only about half of the water in concrete is needed for hydration. The rest is needed to make the concrete flow and be workable. Too much water will cause incomplete curing because the gel particles cannot join together to harden and set.

Curing also gives concrete the ability to hold water in or out. Because so many concrete applications call for the ability to contain water or keep it out, curing is very important. For example, if the walls in the basement of a house do not completely cure, water will seep in from the soil, and moisture will always be present in the house. Concrete cured for only one day would not be waterproof, while concrete cured for three days would be somewhat but not completely watertight. Concrete cured for seven days is completely watertight.

Curing Concrete

One of the most important factors affecting curing is the temperature. Different approaches are necessary when curing concrete in temperatures below 50 degrees Fahrenheit or above 80 degrees Fahrenheit.

Cold Weather Curing

Concrete should never be poured onto frozen soil because the ground will cause the water in the concrete to freeze, halting the curing process completely. The ground should be heated using propane torches.

When pouring concrete in temperatures below 50 degrees Fahrenheit, the concrete should be heated so that it is between 60 and 80 degrees Fahrenheit as it hits the forms. The concrete can be heated by heating the water added to the mixture.

After pouring, protection should be provided for the forms in order to retain the heat in the concrete. This protection can be in the form of straw, plastic, or paper spread directly on the surface of the concrete, sealing the heat and moisture in. The cover should remain over the concrete for at least 48 hours and preferably for four to five days.

Another option for heating the concrete is to build an enclosure around the forms and heat the entire area with fuel-burning heaters. Heaters should be used with caution, because the carbon dioxide they give off will sometimes react with the concrete to form a thin layer of calcium carbonate over its surface, which will be weak and chip off. To avoid this problem, adequate ventilation for the exhaust fumes from the heater is necessary.

The forms should be left around the concrete for as long as possible. They will act as insulation, retaining the heat in the concrete.

One way to test whether the concrete froze during curing is to pour hot water on it. If the concrete has cured properly, nothing will happen. If the concrete did freeze, however, its surface will become soft and mushy. The concrete will need to be chipped or broken out and poured again.

Hot Weather Curing

In hot weather, some important factors need to be considered to allow maximum curing. If outside temperatures are above 80 degrees Fahrenheit, more water will be needed in the concrete mixture to maintain the optimal slump of 1 to 3 inches because some of the water evaporates due to the heat and mixing. High temperatures will also shorten the time that the concrete can be worked or finished because of the more rapid evaporation of the surface water. Reducing the time needed for pouring by having plenty of labor available is important in warm temperatures. The more time it takes to place the concrete, the more water will evaporate, affecting curing.

Hot weather can cause incomplete curing due to the rapid curing of the outside layer of the concrete. Although the outside is cured, the inside may not be. This condition is difficult to detect and may not be noticed until later, when the concrete does not have sufficient strength for a given situation.

Several methods can be used to keep the concrete cool. The easiest method of maintaining the optimal temperature is to cool the ingredients of the concrete as they are mixed. The temperature of the mix can be reduced by adding cold water. Dampening the subgrade will reduce the heating of the concrete as it is poured into the forms. Wet burlap can be placed over the concrete to help cool the surface. Lightly spraying cold water on the concrete will also cool it. However, the concrete should only be sprayed once the surface has been finished and has hardened, so it does not show indentations from the water droplets.

Moist Curing

Another factor that affects curing is moisture. Ideally, concrete should be cured with as little moisture evaporating from the surface as possible. Retaining the moisture on the surface of the concrete is called moist curing. Moist curing can be accomplished using a variety of methods. Some of these methods include placing moist burlap sacks over the surface of the concrete, spraying the surface with water, covering it with waterproof paper, covering the surface with plastic sheets, or spraying the concrete with a curing compound, which places a chemical membrane over the concrete to seal in the moisture. Four main types of curing compound are used: clear or transparent, black, white, and light gray. These curing compounds may cause a permanent change in the color of the surface of the concrete.

Concrete Defects

Concrete defects are faults in the surface of the concrete. They are usually only apparent after curing. These defects have many different causes, including poor materials, improper mix design, improper pouring and curing, or poor workmanship. The faults are difficult, if not impossible, to repair without tearing out the faulty concrete and replacing it.

Honeycomb surfaces result from the use of a concrete mixture that was too dry and needed more water to mix completely. The lack of water causes air pockets around the unmixed dry materials, resulting in a honeycomb structure. To prevent honeycomb faults, the mix must be moist enough. The edges of the forms should also be spaded to avoid dry spots.

Air pockets are holes left in the concrete after curing due to the presence of a confined body of air. They can generally be prevented by spading the edge of the forms. Wiping oil on the surface of the forms will decrease the frequency of air pockets because the oil allows the air to escape more readily.

Rock pockets or gravel streaks are related defects caused by cracks or knotholes in the forms that allow the mortar, which is the cement and water paste, to flow out, leaving pockets and veins of coarse aggregate. While these faults can easily be prevented, they are generally difficult to repair.

Sand streaking involves small ribbons of sand running across the surface of the concrete. This defect is usually caused by a mixture that was too wet. As a result, the coarse aggregates sink and separate out from the rest of the mixture, leaving the fine aggregate to work to the top. This fault is difficult to repair.

If the surface of the concrete is stained red to pink in color, the coloring is the result of the resin in the plywood forms reacting with the concrete. The discoloration will generally happen with forms used for the first time and will diminish with continued use. Using older forms will greatly reduce this problem. The color is difficult to remove from concrete but will fade and disappear in time. Since it is not permanent, this defect does not greatly affect the quality of the concrete.

Rust stains are caused by steel reinforcement that has worked to the edge or surface of the concrete. If the reinforcement is fully covered by concrete, these stains will not occur. The stains can be cleaned from the concrete using a chemical solution of diluted oxalic acid but will reappear as long as the exposed metal is present.

Dusting is the appearance of a powdery material on the surface of newly hardened concrete. Dusting has several different causes, including excess clay or silt in the concrete, premature floating and troweling, the addition of carbon dioxide from heating systems, the condensation of water on the surface before floating and troweling have been completed, dry-heat heaters that lower the humidity too quickly and cause incomplete curing, or inadequate or no curing due to insufficient water in the mixture. Dusting cannot be fixed, only prevented. If the concrete has dusted, it will have reduced strength. The concrete may need to be chipped or broken out and poured again if it is not strong enough.

Scaling occurs when the surface of hardened concrete slabs breaks away to a depth of 1/16 to 3/16 of an inch. This defect may be caused by the freezing and thawing of newly placed concrete, the freezing and thawing of concrete that is not air-entrained, the application of deicing salts on concrete that is not air-entrained, and faulty workmanship caused by finishing the concrete while it was still "bleeding" or giving off water. Scaling cannot be repaired.

Crazing is the presence of numerous fine hairline cracks in the surface of a newly hardened slab due to shrinkage. Crazing can be caused by rapid surface drying by the sun or wind, premature floating and troweling on a moist surface along with the rapid loss of moisture, or the overuse of tools such as a power screed or bull float, which works too much mortar to the surface of the concrete. Crazing cannot be corrected.

Removal of Forms

Forms can be removed when the concrete has cured sufficiently to support its own weight. The amount of time will vary according to the weather. In summer or warm weather conditions, the forms can be removed two days after pouring. In winter or cold weather conditions, the forms should not be removed for at least four to seven days. Forms can be removed in less time if accelerating additives are used; they can cut the curing time in half. Any reinforcement around the forms should be loosened prior to their removal, including all the duplex nails holding the forms together. If the forms were properly coated with oil, they should come away easily, without the use of force. The forms should then be cleaned to remove any concrete residue before storing them away for future use. The slab can be cleaned with water once the forms have been removed.

Summary

Curing is the hardening of concrete, which gives it strength and allows it to resist water. Curing requires temperatures of 65 to 75 degrees Fahrenheit for optimal curing, although curing concrete in hotter and colder temperatures is possible using the proper additives and procedures. Many defects may occur if the concrete is mixed, poured, worked, or cured improperly, resulting in concrete that is weak or has a poor appearance.

Credits

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Lesson 7: Pouring Concrete Walls

Concrete walls are common in construction. They may be used for the sides of a building or for pits to store silage or manure. Also, when building a house, many people prefer to have a crawl space or basement under the house. In order to have these items, a concrete wall must be poured on top of the footings to support the rest of the building. This lesson will discuss the equipment and procedures used in pouring concrete walls.

Tools for Pouring Walls

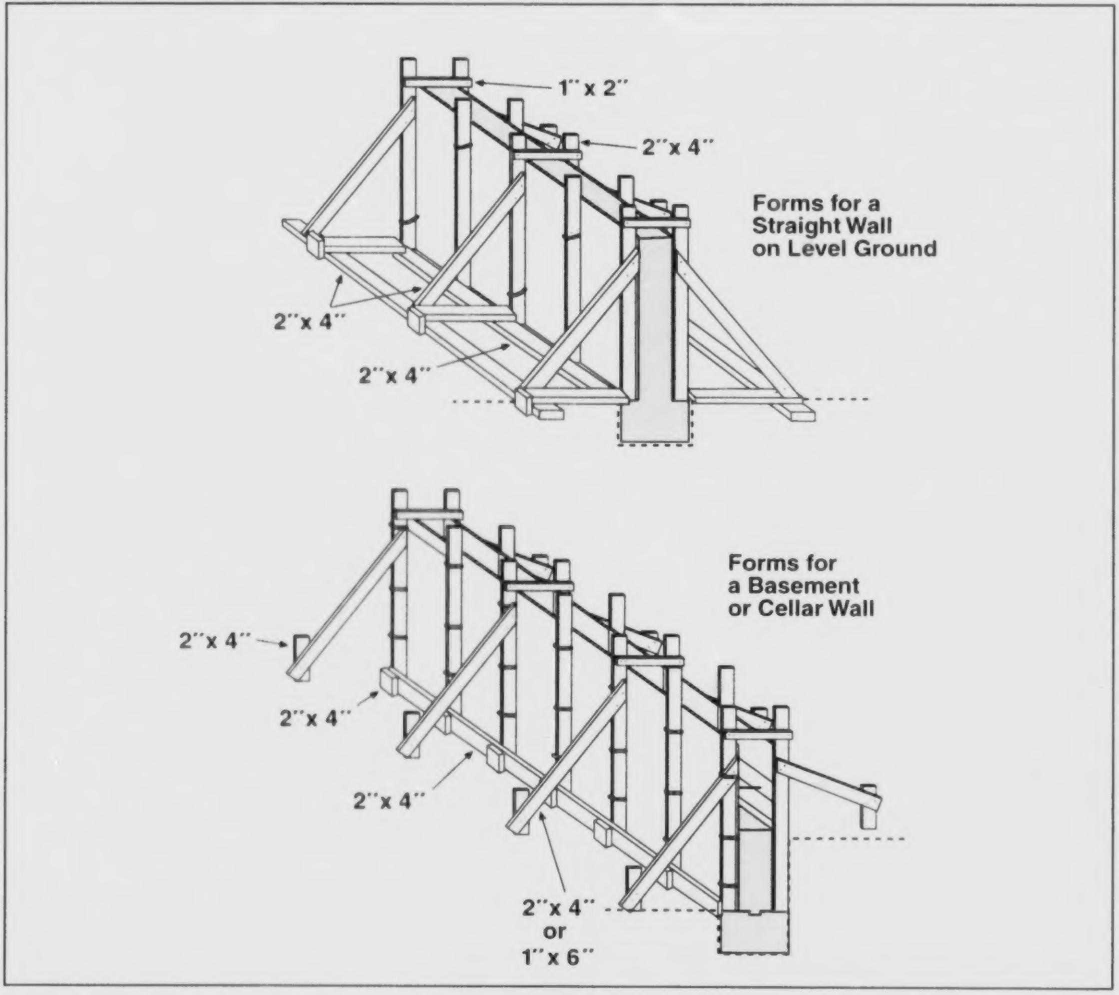
Many of the tools needed for pouring a concrete wall are the same as those used for slabs, although some additional items are necessary. The tools and equipment needed to pour a concrete wall include a trowel, steel tamp rod, shovel, hand level, tape measure, circular saw, and hammer for nailing forms together.

Types of Forms

Several materials are commonly used to construct forms for pouring concrete walls. Wood is the most commonly used material. The forms are typically constructed of plywood made with an exterior glue, which is waterproof and will not come apart when exposed to moisture. Plywood forms are illustrated in Figure 7.1.

Aluminum or metal forms are also made for walls. The use of metal forms will produce straighter walls because the metal does not bend from the

Figure 7.1 - Plywood Forms


1" x 2"
2" x 4"
Forms for a Straight Wall on Level Ground
2" x 4"
2" x 4"
Forms for a Basement or Cellar Wall
2" x 4"
2" x 4"
2" x 4"
2" x 4" or 1" x 6"

weight of the concrete as much as wood forms do. However, metal forms are more expensive than plywood forms.

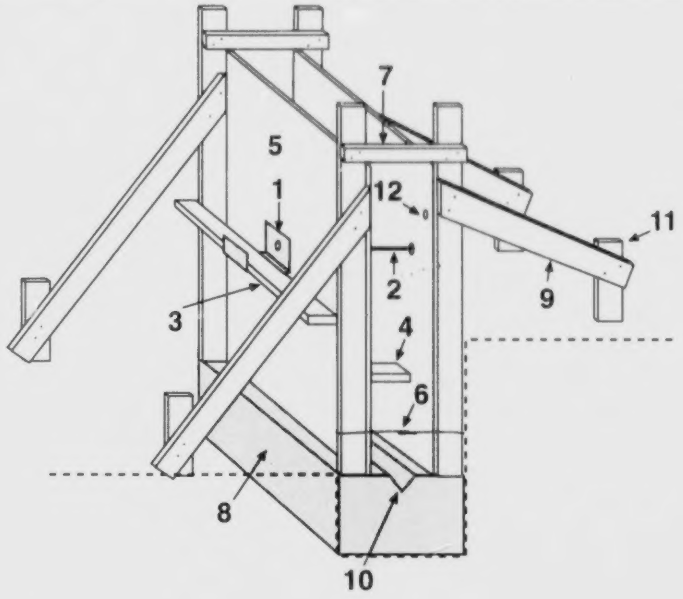
A new type of wall form has been developed in the last few years. These forms are made of Styrofoam with steel mesh embedded in it to add strength to the form. With this type of form, the form is not removed after the concrete is poured into it. Instead, it becomes a permanent part of the wall. Styrofoam forms have several shapes, including one resembling cinder blocks.

Styrofoam forms have several advantages and disadvantages. Less labor is required because the forms are not removed. They allow for construction in all types of weather because moisture will not alter the form as it does wooden forms. The forms are lightweight and snap together for ease of construction. Less bracing is required than with wooden forms. Wiring and pipes can be run through these forms easily because they provide passages through the concrete for plumbing and electricity; with standard forms, wires and pipes will have to be run on the outside of the concrete wall. The forms are energy efficient, as the Styrofoam is an insulator and will serve as insulation for the wall. Finally, the finished product can be finished or painted with exterior paint. A disadvantage of Styrofoam forms is that the forms are not reusable. They are also much more expensive than wooden forms and slightly more expensive than the metal forms.

Constructing Forms for Walls

Since most concrete forms are made of wood, this section will concentrate on how to build wood forms, which have several parts. The parts of a wooden form are illustrated in Figure 7.2.

Figure 7.2 - Parts of a Form



1. Holder
2. Tie Snap
3. Wale
4. Spreader
5. Sheathing
6. Tie Wire
7. 1´´x 4´´ Tie
8. Footing
9. Brace
10. Key
11. Stake
12. Marker Nail

Stake - Stakes are typically made from a 2" × 4" board, which will allow the form to be braced to keep it straight and vertical. For strength, they are placed 4 feet apart or less.

Brace - Braces are nailed to the stake and the form to help keep the forms vertical. Braces can be cut to the correct lengths needed with a circular saw.

1" x 4" tie - The ties keep the two sides of the form apart to give the wall the desired thickness. Each end of a tie is nailed to one side of the form.

Sheathing - The sheathing that forms the sides of the form is typically made of plywood.

Wale - A wale is a 2" × 4" board that prevents the wall from bulging outward due to the weight of the concrete. It is nailed to the form with the wide side down.

Holder - Holders, which are typically made of metal, hold wales and snap ties in place. Once the sheathing is standing in place, the holder is placed over the snap ties and wales are placed in the holder. The holder holds the entire form together.

Snap tie - Snap ties are specially constructed pieces of wire that will run through the concrete wall. Snap ties help hold the forms the correct width apart. The snap tie has a wider spot that allows the holder to clamp tight on it without slippage. Once the concrete has set and before attempting to remove the forms, the holders should be removed, and the ends of the ties can be snapped off by bending them back and forth.

Spreader - A spreader typically consists of a 2" × 4" board cut to a length that is equal to the thickness of the wall. Spreaders are placed inside the form to keep its sides apart while the concrete is poured. During pouring, the spreaders are removed just before the concrete reaches that level.

Wire tie - Like snap ties, wire ties hold the forms the correct width apart. Wire ties are used on the ends of a form, while snap ties are used in the middle. They are constructed of twisted wire and are broken off after the concrete sets.

Key - The key is a groove made in the footing that will allow the concrete from the walls to bond to the concrete in the footing.

Marker nails - Marker nails are driven through the form from the outside to mark the desired height of the concrete if it will not be poured to the top of the form. These nails are removed when the concrete reaches the desired level to allow the surface to be worked with a trowel or float.

Assembly of the forms begins with standing the sheathing upright where the wall will be poured. The holders, snap ties, and wales should be put on to hold the two sides together. Spreaders can be added on the inside of the form at this time. Next, stakes are placed in the ground about 5 to 8 feet away from the form and the braces are cut to the correct distance to reach the stakes. The form should be checked using a level to make sure it is level and plumb, or straight up and down. If the forms are not level and plumb, adjust the braces until the form is correct. Then the braces are nailed to the forms and the stakes to hold the forms in the correct position. After the braces and stakes are in position, the wire ties are placed on the ends of the forms, and the 1" x 4" ties are secured to the ends of the forms with duplex-head nails.

The forms must be square, because if they are not, the building will not be square. The diagonal method is used to check whether they are square. If the diagonals are not equal, the form will have to be adjusted.

All of the pieces on the form must fit tightly together, and the forms must be strong. They should be checked prior to pouring the concrete. Forms that are loose or weak will lead to blow-outs, or concrete flowing out of weak spots in the form that break due to the weight of the concrete. Usually these weak spots occur at corners or where two forms meet. These spots can be braced using additional 1" x 4" ties and duplex-head nails attached diagonally across the corners, or across the joint where the forms meet.

High quality lumber must be used in constructing forms. Weak spots from cracks, knot holes, or other problems will reduce the strength of the form.

Reinforcement of Walls

After the forms have been set up and are square, reinforcement can be added. Just like slabs, walls require reinforcement. Typically they are reinforced with rebar. The rebar should be placed in the middle of the wall at an equal distance from each side of the form, and it should not stick out the top. The rods are placed length-wise through the walls, spaced 8 to 12 inches apart. Rods are driven vertically in the ground every 4 feet to support the horizontal rods. The vertical and horizontal rods are tied together using thin wire.

Pouring the Walls

The process for pouring concrete walls is relatively simple. Before filling the forms with concrete, they should be lightly oiled to prevent the concrete from sticking. The concrete is then poured from one end or corner, working along the wall. The corner must be filled before moving on to the rest of the wall. Enough concrete should be poured in one spot to fill the form before moving so that the concrete does not have to be shoveled backward to fill low spots. Spreaders must be removed as the form is filled. When the form is filled to the desired level, the steel tamp rod is run up and down through the concrete to help work out air bubbles. As soon as one wall is finished, another wall can be started if the forms are in place.

After each of the walls has been poured, the top surface of the concrete must be smoothed and leveled. The top surface needs to be flat and relatively smooth so a wall that is built on top of it will seal against the concrete and not allow air to leak into the building. This task can be done using a small trowel or a board cut the width of the wall. The tool is worked along the top of the forms in a process similar to screeding.

After the first wall has been leveled and smoothed and the surface starts to dry, anchor bolts can be inserted into the concrete. Anchor bolts are standard bolts that are placed with the head of the bolt in the moist concrete. These bolts will anchor the wooden portion of the structure. They should be at least 3/8 of an inch in diameter and are typically 4½ to 5 inches long. Anchor bolts are generally set at least 2 inches into the concrete. The bolts should be straight.

Anchor bolts are spaced 4 to 6 inches apart along each side of the building, with one bolt set in from the corner near each end of a wall. The distance between them depends on the wind loads that will affect the structure. They should be only 4 inches apart in areas with more winds but may be further apart in areas with little wind. The anchor bolts will help secure the walls to the foundation in strong winds. The bolts should also be placed where they will not interfere with the upright studs in the walls. If an anchor bolt is located where the stud will be, either the stud will have to be moved, which would weaken the wall, or the bolt will have to be cut off, which decreases the wall's ability to resist winds

Before the forms are removed, concrete walls should cure for at least one week, preferably longer. The concrete will take longer to cure because the outside air is not reaching as much of the surface.

When the concrete has cured enough, the forms are removed. All holders and wales are loosened first. The braces and stakes are then removed. Finally, the sheathing is carefully removed. They should come off without the use of excessive force. After the forms have been removed, the snap ties can be twisted back and forth until they break or snap off to leave a relatively smooth wall surface. If wire ties were used, cement paste can be used to fill in the holes left in the concrete.

Preventing the Entry of Moisture

Even though concrete is mostly waterproof, moisture may still flow through, especially at joints or cracks. To completely seal a concrete wall, the use of some method of repelling or removing moisture is necessary. A vapor barrier is a specially constructed protective material attached to the inside of the underground portion of a concrete wall to eliminate condensation. Waterproofing materials painted on the outside of a wall also prevent the entry of the water. Typically, they are made of polyurethane, rubber, tar, or other waterproofing compounds. It may also consist of a layer of polyethylene plastic glued to the outside of the wall that will repel water from the soil. Another way to keep water from entering the concrete is the use of a waterstop. Waterstops are synthetic materials placed between concrete construction joints to stop water from entering through the joints. Drainage pipes can also be placed around the structure to move excess water away, reducing the chance of water problems.

Summary

Pouring concrete walls is an important step in building construction. If the forms are built and braced correctly, the building will be square and strong. Care should be given to carefully constructing the forms, pouring the concrete, and allowing the concrete to cure. Properly reinforcing the concrete will yield much stronger walls that can withstand the years of pressure and stress from the weight of the building. A water stop can be used to completely waterproof a wall.

Credits

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Lesson 1: Electrical Safety

Electricity is all around people every day. It lights their homes and workplaces, keeps them warm and cool, and cooks their food. Electricity is also a major energy source utilized in agriculture. While electricity is a helpful tool, it can be a hazard if not respected. Estimates from the National Electrical Safety Foundation indicate that the electrical systems in homes were involved in 43,000 fires, 330 deaths, and 1,720 injuries in 1993. In 1992, their data shows an estimated 530 electrocution deaths.

Basic Rules of Electrical Safety

Electrical safety is a major consideration in the home and in agricultural operations. In electrical safety, the primary focus is on two main concerns: shock and fire. Anyone who has ever touched an electric fence has felt the effects of an electric shock, which is the passing of an electric current through the body and the body's reaction to it. An electric shock will affect the rhythm of the heart, possibly leading to serious injury or death.
Everyone is familiar with fires, but an electrical fire generally begins unnoticed. Electrical fires have two main causes. Some fires begin because wires overheat. This situation generally occurs when a restriction exists in the flow of electricity through the conductor or if a system is overloaded. The second way electrical fires begin is with an electrical current jumping a gap, creating sparks. Broken wires or improper electrical connections may produce a gap.

How can these hazards be reduced? Anyone working around or using electricity must take note of a number of precautions. During the installation and repair of electrical systems, the main power source should always be disconnected before working with the system. Also, state and local electrical codes should be followed when installing new systems. Manufacturers' instructions for the installation and use of electrical equipment are another important source of information about the proper procedures to use. Short cuts during installation can lead to hazards later.

The use of extension cords is another factor that can create electrical hazards. Extension cords are not a permanent fix for a lack of wall outlets. Cords should only be used for a short period when the cords on electrical equipment do not reach an outlet. Extension cords should not be placed under items, such as rugs or other things that put weight directly onto the cord. Placing them in high traffic areas can also lead to insulation damage and a restriction of electrical flow and should be avoided. A long extension cord should always be uncoiled before plugging it in. A coiled conductor creates greater resistance to electrical flow, which can lead to voltage loss, blown circuits, and fire hazards. If an extension cord becomes warm or smells of burning rubber, its use should be discontinued immediately.

Fuses and breakers, which are safety devices designed to shut off electrical flow, can be a source of electrical hazards. Activation of a fuse or breaker device is an indication that a problem exists with the electrical system. The problem may be an electrical overload, with too many items running on a system, or something more serious within the electrical circuit. Checking out the system and correcting the problem is important before replacing the fuse or resetting the breaker. A higher capacity fuse or circuit breaker should never be used for a repair. Electrical systems are designed to carry a certain load, and an attempt to increase this load will burn out the system.

A situation that can be extremely hazardous, and one in which agricultural electricians often find themselves, is performing an installation near wet areas. Water is an excellent conductor of electricity, and if electricians are working on a system or using a tool in a damp environment, they can become a conductor for the electrical flow as it seeks a ground. While working with electrical systems or appliances in areas that are wet or damp, making sure that the power is disconnected is important. Cabinets, shelves, and stands should be utilized to keep tools and appliances dry. GFCI outlets, special outlets designed to interrupt electrical flow in hazardous situations, in noncorrosive plastic device boxes should be installed in wet or damp areas.

As with most hazardous situations, misuse due to the human factor tends to be the single greatest cause of electrical mishaps. Electricity, although beneficial, can cause large amounts of property damage and lead to loss of life, so following suggestions for safe installation and use of electrical systems is vital. When working with electricity, remember that safety devices put in place by manufacturers have a purpose and do not damage or disable them. Do not use any electrical product that is damaged in any way. Do not remove a plug from an outlet by pulling on a cord, and never carry a power tool by its cord.

Joining two wires that are composed of different metals can pose a hazard. They can create a fire hazard. A special type of connector should be used to prevent problems.

Sources of Electrical Defects in Equipment

Defects that occur in electrical equipment have six common sources. They are problems with the ground wire, open conduits, damage to the insulation, damage to equipment, lack of maintenance, and misuse.

Ground wire defects occur when the ground, or neutral, wire is missing, broken, improperly connected, or not connected at all. These problems can lead to shorts in the system and a possible shock hazard to anyone using equipment connected to the line.

Conduits are metal or plastic tubes that enclose electrical wires. Open conduits are defects that lead to wire damage. When a conduit is left open, damage may occur from water entering the conduit. Open conduits also allow for wear and deterioration of the insulation. This type of defect can create a short circuit.

Insulation damage occurs when the insulation becomes worn, wet, or oily. Damaged insulation can lead to short circuits, shocks, and fire hazards.

Another source of defects is damage to equipment that occurs during manufacturing or installation and use. Defects normally occur in switches, receptacles, and extension and appliance cords. This type of defect can lead to shock and fire hazards.

Poor equipment condition may be caused by a lack of maintenance. Dirty, improperly adjusted electrical equipment can overheat, throw sparks, and short out. Poor maintenance can also create a fire hazard.

The most common source of defects is misuse through carelessness. Carelessness may result in the misuse of equipment, improper wiring practices, limited knowledge of electrical systems, and working around electricity in wet environments without proper precautions.

Electrical Injuries

Electrical injuries can occur anywhere a source of electricity is present. Coming in contact with an electrical source can send a current of electricity through the body. The amount of current will depend on the degree and quality of the insulation on the electrical source and the electrical resistance of the skin. Skin resistance is at its lowest when the skin is damp or if the location is wet. In this situation, a current of .006 amps can electrocute a healthy individual in less than one second.

What should be done if someone gets shocked? For someone receiving an electric shock of 120 to 240 volts, the first step is to disconnect the source of the electric current, if possible. If it cannot be disconnected, a long pole or other item of nonconductive material, such as wood or fiberglass, is needed. The person holding the pole should insulate himself or herself by making sure to avoid any liquids or wet areas and then use the pole to move the person or the conductor, depending on which is easier and safer to move.

If the power source is over 240 volts, as is the case with overhead wires, anyone in the area should assume that the downed wire is live and can kill. Everyone should be kept at least 200 feet away because the static electricity in the air can arc to individuals wearing any type of metal. Rather than trying to help the victim themselves, they should contact emergency personnel immediately and call the power company to give them the exact location of the incident.

In either case, rescuers should never attempt to grab a person in direct contact with a live wire. The electrical current will "freeze" muscles, thus compounding the situation and putting the rescuer at risk of electrocution and death.

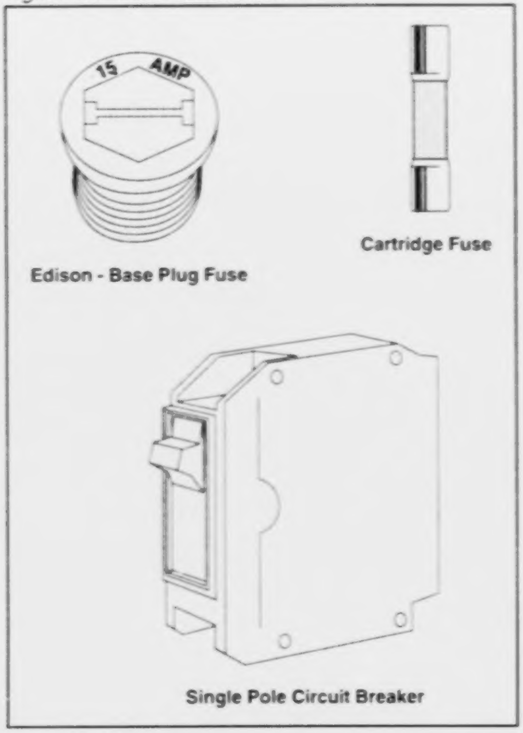
First aid should be given once the victim is removed from the electrical source. Rescuers should check to see if she or he is conscious and then check for signs of breathing and a pulse. If they are trained in the use of CPR, they should perform CPR on the victim until emergency personnel can arrive. Victims of electrical shock often suffer burns. If burns are present, they should be covered with a dry, sterile dressing. Rescuers should not attempt to cool electrical burns since efforts to soothe them may only make the situation worse and can lead to further damage. Finally, the victim should never be moved unless an immediate threat to his or her safety exists. Due to the nature of an electrical injury, the victim may experience damage to the spine that would be worsened by being moved.

Types of Circuit Protection

An overcurrent device limits the amperage in any wire to the maximum permitted. Fuses and circuit breakers are overcurrent devices. Both of these devices are rated by the number of amps that will travel through the overcurrent device without triggering it. The size of the wire used in the system will determine the amperage rating of the overcurrent device used. Different types of overcurrent devices are shown in Figure 1.1.

A fuse is a short piece of metal that has been experimentally tested to melt at a predetermined flow of amps. This piece of metal is housed in a nonconductive material for the purposes of protection and removal. The most common type of fuse is the plug type, which screws into the electrical service panel, the box located where power enters the building. If a fuse blows, it should be replaced with one of equal amperage, never with one of higher amperage.

Figure 1.1 - Overcurrent Devices



The circuit breaker is a semi-permanent device positioned in the service panel during wire circuit installation. This device does not require replacement when a break occurs in the circuit. The circuit breaker resembles a toggle switch with a handle. It has four switch positions: on, tripped, off, and reset. Inside the circuit breaker is a mechanism that "trips" the breaker and disconnects the load in an overload situation. Because of the ease of resetting a circuit breaker, this overcurrent device is the type most commonly used.

Fuses and circuit breakers normally provide sufficient protection for electrical equipment. However, they do not always entirely protect people from being shocked. Therefore, ground fault circuit interrupters (GFCI) should be used in certain situations. They interrupt the flow of electricity in order to prevent electrical shock if a fault exists in the circuit that will not affect a fuse or circuit breaker. GFCIs will be discussed in more detail in Lesson 4 of this unit.

Summary

Electrical safety concerns everyone. Being aware of electrical hazards will enable an individual to safely work with electricity. He or she must understand the safety devices needed and know what to do in an electrical emergency.

Credits

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Lesson 2: Electrical Terminology

In addition to safety practices, anyone working with electricity needs to understand the basic terminology associated with it. Without a knowledge of these basics, it is impossible to work with electricity effectively.

Electrical Careers

Power line installer and repairer
Power line troubleshooters
Cable splicer
Construction electrician
Maintenance electrician

Terms and Definitions for Electricity

In every occupation, including those that require working with electrical systems, terms and definitions exist that an individual must learn to be competent in that field. This terminology includes the names of devices used in electrical systems, types of current, units of measurement, and common problems in electrical systems.

A typical electrical system contains a number of components. The conductors are the wires through which the electrical current is carried through a circuit, which is the complete, uninterrupted path of electricity. Most conductors are made from copper, aluminum, or copper-clad aluminum. In the system are positive, or hot, wires that act as the conductors of electrical power. The insulation on these wires is typically color-coded red or black. The other wires, which are called neutral wires, conduct electricity from the appliance back to the source, completing the electrical circuit. These wires are color-coded white or gray. Insulation made of plastic or rubber forms the protective covering on the wires. All electrical systems should be grounded to function safely. Grounding is the electrical connection from the appliance or piece of equipment to the earth.

The system also contains circuit protection devices in the form of fuses or circuit breakers. The fuse is a safety device that prevents the overload of an electrical circuit by "burning out" and interrupting the electrical flow. A circuit breaker is an automatic flip switch located on an electrical circuit that breaks, or shuts off, the current when overloaded.

An electrical system may use one of two types of current. Alternating current (AC) is the most common type of electricity supplied to the home or farm. The electrical current alternates, or changes its direction of flow at regular intervals, usually 60 times per second. Direct current (DC) is electrical current that flows steadily in one direction through a conductor, either from the positive pole to the negative or from the negative to the positive. A generator or battery produces direct current.

The three major units of measurement in electricity are amperage, voltage, and wattage. Amperage is a measurement of the flow of current through an electrical system; it is measured in amperes, or amps (A). Voltage is the measurement of the pressure created by electricity moving through the conductor. It is measured in volts (V). Wattage is the measurement of the total electrical power within a system. Wattage is calculated by multiplying amperage and voltage and is measured in watts (W). A term most people are familiar with is kilowatt (kW), which is 1,000 watts. Electrical meters read electricity in kilowatt hours, which is the use of 1,000 watts of electricity in one hour. Another important measurement is resistance. Resistance, which is measured in ohms, is the opposition to the flow of current as it moves through a conductor.

Two common problems that occur in electrical systems are voltage drops and short circuits. Voltage drop is the loss of electrical pressure from the source to the point of use. This problem normally occurs in overload situations. Short circuits occur when wires in the same circuit come into contact, causing the flow of electrical current to move from its desired path. Worn insulation or loose connections at the appliance or piece of equipment may cause a short circuit.

The National Electrical Code (NEC)

In 1911, the National Fire Protection Association (NFPA) sponsored the development of the National Electrical Code (NEC). The goal of the NEC is to address four issues: changing power needs in the United States, safe user practices of new technology, minimum standards for electric wiring practices and materials used nationwide, and increased energy use in the home, workplace, and community. The electrical code is printed periodically in book form. Topics covered in the

1996 edition include: wiring and protection, wiring methods and materials, equipment for general use, special occupancies, which are buildings for particular purposes, special equipment, special conditions, and communication systems. Revisions to the NEC are done under the supervision of the NFPA and identify new issues and technologies related to electrical installations.

Enforcement of NEC Guidelines

The NEC is basically a reference and resource for state and local governments and for insurance companies. Government agencies utilizing the NEC include the Occupational Safety and Health Administration (OSHA) and state and local building inspectors. Insurance companies may require the use of NEC guidelines in buildings they insure, primarily for those structures being built for rental or resale. Through these entities, the regulations found in the NEC handbooks are enforced.

UL Listings

The Underwriters Laboratories, Inc. (UL) is an independent, not-for-profit testing and certification organization that evaluates products, materials, and systems, such as electrical outlets and appliances, in the interest of public safety. The UL has been functioning in this capacity for over a century.

A UL listing means that representative samples of the product have been tested and evaluated with reference to nationally recognized safety standards for electric shock, fire, and related safety hazards. A UL listing is important because it provides a degree of product quality assurance, which is vital when dealing with an item that has the potential of being a fire or shock hazard.

Summary

Certain terms are very important to know in order to understand electricity. Knowing these terms will help to understand the concepts relating to electricity and how it works. Individuals working with electricity must also understand and utilize those practices outlined in the NEC. Products with a UL listing are useful because their quality has been assured.

Credits

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Lesson 3: Wire Types and Uses

The size and type of wire used for wiring are among the most important considerations in electrical installation. Different types of wire may be used, depending on the type of structure, its uses, and the electrical load of the circuits.

Wire Types

Traditionally, electrical wire has been made from copper or aluminum. However, copper wire is the best conductor for most purposes. It is also the most widely used type of wire. Compared to copper, aluminum is a relatively poor conductor, and copper-clad aluminum is only slightly better. Aluminum wire must be two sizes bigger than copper wire would be to produce similar results.

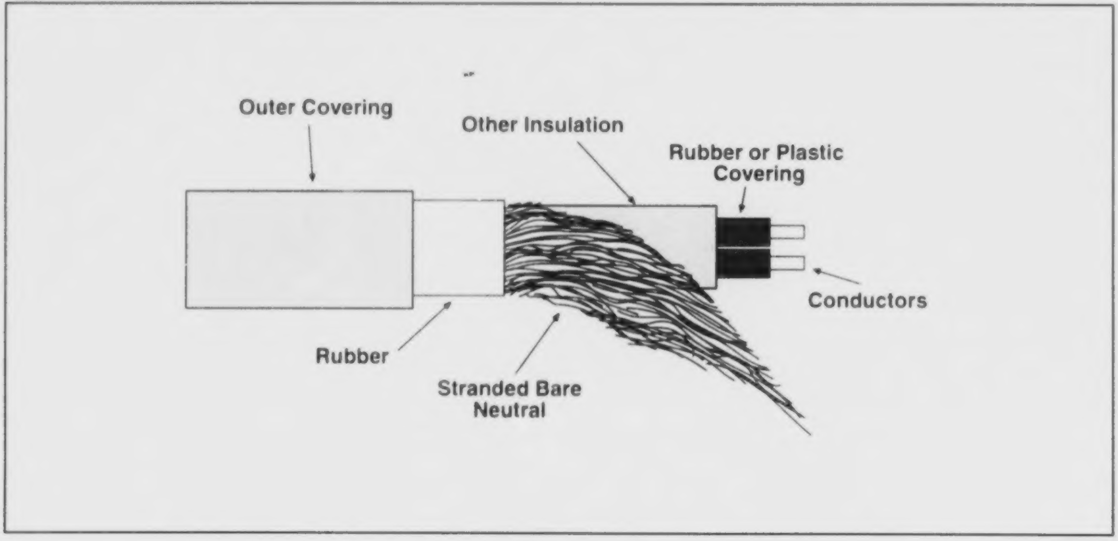
Three categories of electrical wiring are typically used: service wires, interior wires, and cables. Service wires carry power into the home or building to the service entrance panel. The wires are either SE wires for overhead installations or USE wires for underground service. Service wires consist of a bundle of wires, with fine strands of uninsulated wire wrapped around the insulated wires, as shown in Figure 3.1. The uninsulated wire is the grounded neutral.

Interior wires, which are wires that must be protected from the elements, can be divided into two categories, Type T and Type R. Type T is the most commonly used interior wire type. This wire has thermoplastic insulation, which is a single layer of plastic compound that covers the individual wire. The insulation strips off easily and cleanly, making the wire easy to use. Type R wire was previously rubber coated for insulation, but advances in synthetic polymers have led to the use of these substances instead. This type of wire may also have a moisture-resistant, flame-retardant outer covering. Type R wires are rarely used in modern construction, although they are still found in many older structures.

Based on the wire's ability to withstand environmental and temperature conditions, Type T wires are divided into four categories: TW, THW, THHN, and THHW. TW wire is moisture resistant. However, the wire may not be buried directly in the ground. The insulation can withstand a maximum temperature of 140 degrees Fahrenheit. THW wire is considered to be both moisture and heat resistant. Its insulation has a heat rating of 194 degrees Fahrenheit. Like TW wire, it may not be buried in the ground. The insulation of THHN wire can also withstand a maximum temperature of 194 degrees Fahrenheit, but it may be used only under dry conditions. THHW wire, on the other hand, is designed for wet or dry conditions, with insulation that can handle a maximum temperature of 194 degrees Fahrenheit in dry conditions and 167 degrees Fahrenheit in wet conditions.

The three categories of Type R wires are RH, RHH, and RHW. RH wire is designed for dry

Figure 3.1 - Service Wire



conditions and a maximum temperature of 167 degrees Fahrenheit. RHH is also designed for dry conditions but has a higher temperature rating of 194 degrees Fahrenheit. RHW wire will work in either wet or dry conditions and has a temperature rating of 167 degrees Fahrenheit.

Cables form another category of electrical wire. To make a cable, individual wires are assembled and covered with a protective element. Cable is the predominant form of structural wiring used in the modern construction industry. The NEC has developed a set of identification requirements that indicate the information that must be present on the cable, as illustrated in Figure 3.2. This information includes the following elements.

- Size of the wires
- Insulation type
- Voltage rating
- Testing agency
- Number of conductors
- Outer finish or covering

The three main types of cables are nonmetallic sheathed cable, armored cable, and flexible cord. Nonmetallic sheathed cable is the most common type of cable used in building construction. It typically contains two or three THHN or THHW wires with an additional bare ground wire. This cable is easy to install, clean in appearance, and highly economical. Nonmetallic sheathed cable comes in three forms: NM, NMC, and UF. NM is used in dry conditions and not in barns or other damp locations on agricultural operations. NMC is designed for damp or corrosive locations but cannot be buried underground. UF, or underground feeder, is identical to NMC but can be buried directly underground.

Another type of cable is armored cable. This cable is used in dry locations only. It normally contains TW, THW, or THHN wires. The individual wires are enclosed in a tough paper overwrap and spiral steel armor.

The third type of cable is flexible cord, which connects electrical devices to outlets. Various types of flexible cord are available. Types SPT-2 and S are used for connecting lamps, appliances, and other devices to outlets. Type SPT-2 has wires imbedded in plastic and is used for small appliances, such as lamps and radios. Type S is heavier and is used for applications where heavy use and abuse is possible, such as for power tools. The wires are bundled into a round assembly insulated with plastic or rubber. Another type of flexible cord is HPN, or heater cord. This type of cord is used with heating appliances, such as toasters and irons.

Wires for Agricultural Wiring

Agricultural structures pose slightly different requirements than homes and businesses in terms of electrical work and wiring. Section 547 of the NEC describes the basic criteria. The NEC addresses two main categories of agricultural

Figure 3.2 - Cable

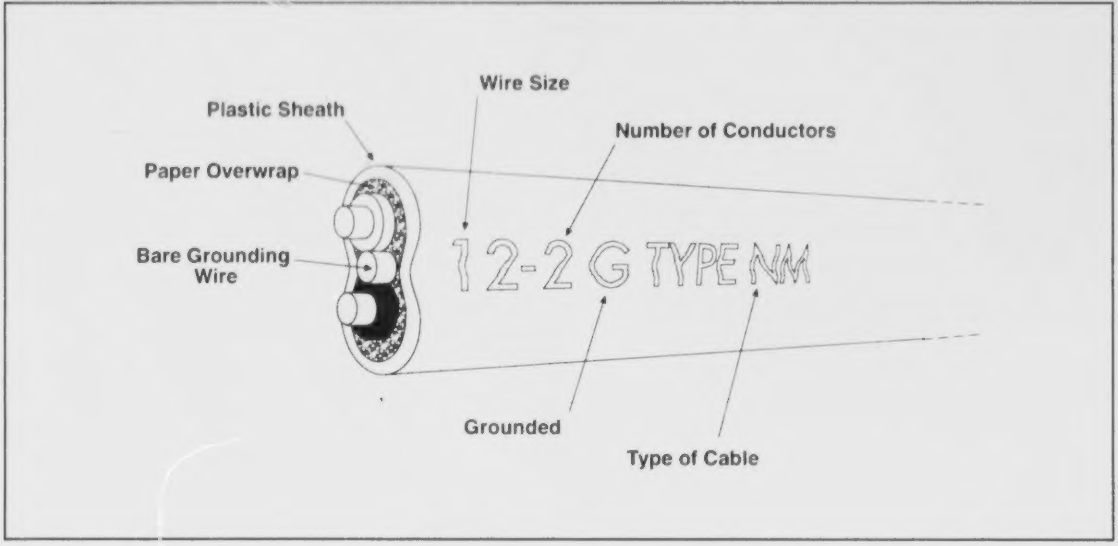
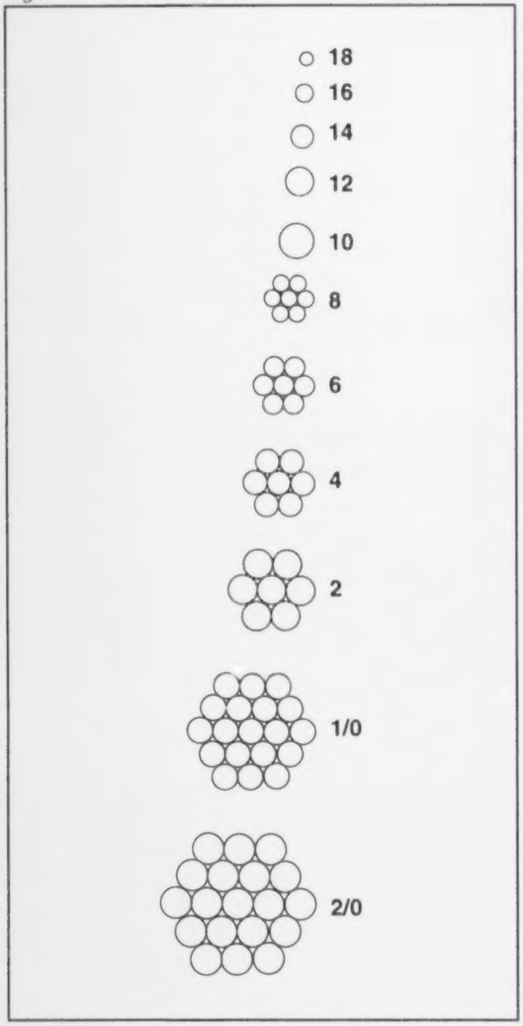


Figure 3.3 - Wire Sizes



buildings. In the first category are buildings where excessive dust and dust with water may accumulate. Such buildings include totally enclosed and environmentally controlled poultry and livestock structures, confinement systems where litter, dust, and feed dust may accumulate, and feed mills. The second category consists of buildings with a corrosive atmosphere. These structures include totally enclosed and environmentally controlled areas where poultry and animal excrement may cause corrosive vapors in the confinement area, where corrosive particles may combine with water, or where the area is damp and wet because of periodic washing and sanitizing.

The types of wires approved for agricultural buildings are UF and NMC cables as well as other cables or raceways, which are enclosures like tubing that the cable runs through, that are highly resistant to corrosion. Both UF and NMC cables are approved for the two categories of structures, although UF cable is generally to be used underground; it can be used aboveground, but not in highly corrosive situations. The wires and fixtures in buildings with excessive dust must be "dust-ignition-proof" to protect against dust fires and explosions. Therefore, wires and fixtures should not produce arcs, sparks, or heat that is sufficient to cause the dust to ignite.

The Importance of Wire Size

Wire size is measured using the American Wire Gauge (AWG), an industry-adopted scale that sets standard sizes. Smaller AWG numbers represent larger wire sizes. Number 14 wire is the smallest size allowed in most structures; however, in agricultural structures, the wire used should not be smaller than number 12 wire. Wire sizes range from 4/0, which is about ½ inch in diameter, to 20+. Figure 3.3 shows some common wire sizes.

One reason that wire size is an important consideration is ampacity. Ampacity, which is measured in amperes, is defined as the safe carrying capacity of the wire. The greater the amount of amperes flowing through the conductor, the greater the amount of heat produced. Doubling the amperes without changing the wire size will increase the heat output by four times. If the amperage is too high for a prolonged period, it may damage the insulation and lead to a fire.

Wire size is also important because of voltage drop. Voltage drop is the loss of electrical pressure over a length of wire. While some voltage drop is expected, and a 2 percent drop is acceptable, excessive voltage drop is wasted power. Machinery and equipment that run at lower than rated voltages work inefficiently. At 90 percent of its rated voltage, a motor produces only 81 percent of its normal power, and a lamp produces only 70 percent of its normal light output. Wire size affects voltage drop; a larger conductor provides a larger surface for more complete electrical flow. If more amperes are pushed through a conductor than its size allows, increased friction results, causing heat buildup and voltage drop.

Selecting the Proper Wire Size

Some key information is needed before the appropriate wire size can be determined. The following information is required for calculating wire size: amperage load, voltage, wattage, and the length of run. The type of wire installation used, such as open air or buried wire, is also important, since larger wires are needed overhead for support and because of the voltage leak that occurs in these situations.

Using the information given in Table 3.1, wire size can be determined by using amperage, voltage, wattage, and the length of the run. Suppose that a wire carrying 30 amperes at 240 volts will run a one-way distance of 120 feet. Thirty amperes at this voltage is 7200 watts; to cross a distance of 120 feet requires a number 8 wire. When using the table given, always round up the calculated wattage in consideration of future growth and increased power conditions. If the distance the wire is to span falls between the distances given on the table, use the longer distance and the larger wire.

Use the section of the table describing the wire sizes needed for 240 volts whenever calculating the sizes of wires running into the service panel and to appliances and equipment that require 240 volts. A good strategy is to calculate the wire size as if it will be carrying 240 volts, because the wire can then be used for either 240 or 120 volts.

Beyond the basic considerations, overhead wires pose other requirements. The wires need to be large enough to support themselves without sagging and to maintain some rigidity under heavy snow loads. To carry 600 volts or less, AWG 10 is recommended for spans up to 50 feet in length. Number 8 wire is needed for longer spans. To carry over 600 volts, AWG 6 is needed where individual conductors are used, and number 8 where conductors form a cable. For all wiring distances over 150 feet, a second pole is recommended.

Feeder Wires

Electrical power is brought to the farm by a power company. The service drop from the power company ends at a centrally located yard pole rather than a building. Feeder wires span the distance from the electrical service equipment at the pole to the service panel at each individual structure, as illustrated in Figure 3.4. They are either SE or USE wire, depending upon whether the service will be installed overhead or underground.

Figure 3.4 - Feeder Wires

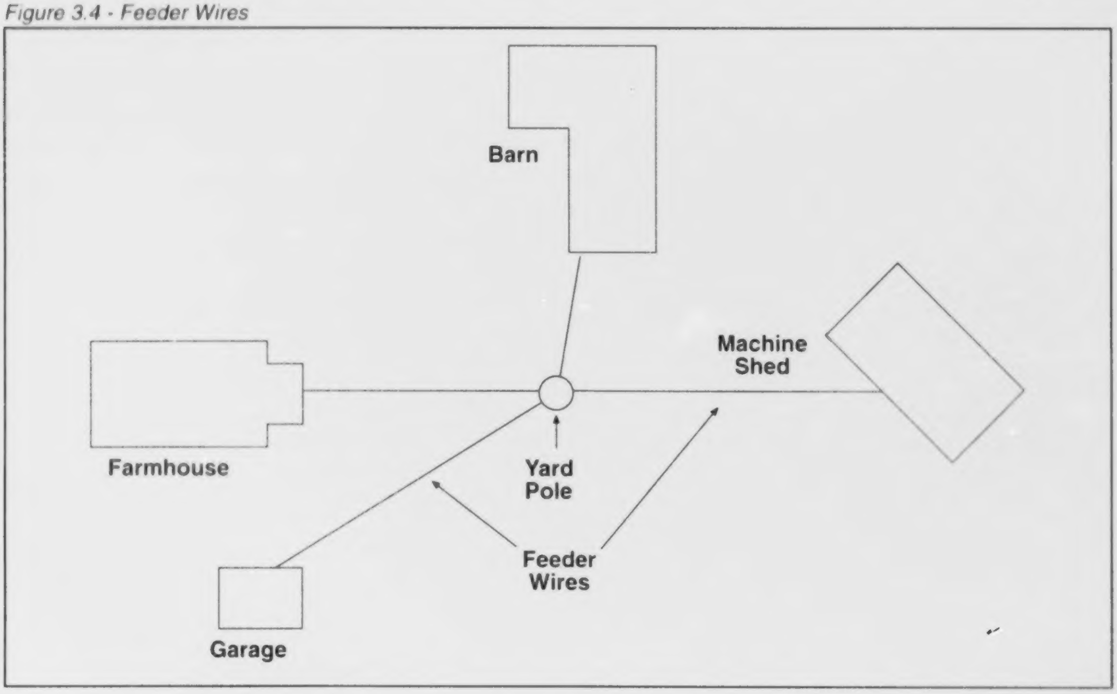


Table 3.1 - Wiring Tables

One-Way Distances (in Feet) at 120 Volts, Single-Phase, with 2% Voltage Drop

		AWG Wire Sizes									
Amps	Watts	14	12	10	8	6	4	2	1/0	2/0	3/0
5	600	90	140	225	360	570	910				
10	1200	45	70	115	180	285	455	725			
15	1800	30	45	70	120	190	300	480	765	960	
20	2400	20	35	55	90	145	225	360	575	725	915
25	3000	18	28	45	70	115	180	290	460	580	730
30	3600	15	24	35	60	95	150	240	385	485	610
40	4800			28	45	70	115	180	290	360	455
50	6000			23	36	55	90	145	230	290	365

One-Way Distances (in Feet) at 240 Volts, Single-Phase, with 2% Voltage Drop

		AWG Wire Sizes									
Amps	Watts	14	12	10	8	6	4	2	1/0	2/0	3/0
5	1200	180	285	455	720	1145					
10	2400	90	140	225	360	570	910	1445			
15	3600	60	95	150	240	380	610	970	1530		
20	4800	45	70	115	180	285	455	725	1150	1450	
25	6000	35	55	90	140	230	365	580	920	1160	1450
30	7200	30	48	75	120	190	300	480	770	970	1220
40	9600		36	56	90	140	230	360	575	725	915
50	12000			45	70	115	185	285	460	580	725
60	14400				60	95	150	240	385	485	610
70	16800				50	80	130	205	330	410	520
80	19200					70	115	180	285	360	460
90	21000					60	100	160	260	320	405
100	24000					55	90	145	230	290	365
125	30000						75	120	190	240	300
150	36000							95	150	195	245
200	48000							70	115	145	185

Feeder Wires and Demand Load

The size of the feeder wire depends on the demand load for a structure. The demand load of an agricultural structure is typically considered to be the amount of power that will likely be needed at any given time. Normally, the minimal calculated demand load is about 35 percent of the total connected load, which is the maximum amount of power that would be drawn if all circuits and appliances were in use. A demand load factor of 35 percent (.35) suggests that only 35 percent of the electrical system will be active at a given time. However, depending upon the type and use of the electrical system within the structure, this percentage may be higher. The approximate amperage that will be in use will determine the necessary feeder wire size.

Feeder Wire Size, Length, and Voltage Drop

The length of the wire plays a major part in determining the size of the feeder wire. Because length tends to be a fixed factor once the yard pole is in place, the size of the feeder wire must then be increased to avoid voltage drop if demand loads or amperage requirements increase. A good rule of thumb is to place the pole or power source as close as possible to the building or buildings that will have the highest electrical use, which will reduce the costs associated with buying larger wire sizes as well as the effects of voltage drop. It is important to note that the wire distances given in Table 3.1 are based on a 2 percent voltage drop. If a higher voltage drop is acceptable, the length can be increased. For example, for a 4 percent voltage drop, double the distance shown on the table for each wire size.

Circuit Needs of a Structure

Several rules of thumb may be applied when calculating the circuit needs of a structure, although the codes required for buildings may vary by county and type of structure. For example, at least one lighting and/or convenience outlet is required for every 150 square feet of floor space. Each square foot of floor space should have a minimum of 3 watts of lighting; most structures will require more. Convenience outlets should be installed every 12 feet along walls.

Various circuit sizes are recommended for branch circuits, which are separate electrical paths that extend from the service entrance panel and have their own overcurrent protection devices. For 500 square feet of floor space, a branch circuit with a 20-amp minimum is necessary, while a 15-amp branch circuit is the minimum needed for every 375 square feet of floor space. A water heater requires a branch circuit of 30 amps, carrying 220 volts. A ventilation fan calls for a branch circuit of 20 amps, carrying 110 volts. Both a water pump and workshop bench should have a branch circuit of 20 amps, carrying 110 or 220 volts.

Calculating Load

To calculate the load of an agricultural building, complete the following steps. An example is given to show how the steps are applied. The same process can be used to calculate the total load and demand load of branch circuits.

- List the number of circuits, special appliances, motors, etc. to be used.
- Determine the total volt-amperes (VA), or watts (W), for each by multiplying their amperage and voltage requirements; then multiply each one by the number of power outlets of that type.
- Add the numbers to determine total wattage of the structure.
- Multiply by the demand load factor. If in doubt about the size of the demand load, use a higher percentage to take into account future growth and the maximum electrical use at a given time.

Suppose that a structure has ten lighting circuits, five outlets, three motors, and a heater all at 240 volts. The distance from the yard pole to the building is 100 feet. The demand load factor will be 50 percent. What would the demand load be?

Circuits and appliances:

10 lighting circuits, generally calculated at 400 W
5 outlets, generally calculated at 200 W
3 motors, at 1200 W, 2000 W, and 3000 W
1 heater, stamped with a rating of 5000 W

W requirements:

10 × 400 W = 4000 W
5 × 200 W = 1000 W

(1200 W + 2000 W + 3000 W) × 0.50 = 3100 W (Use .5 as a multiplier if all the motors do not run at the same time.)
Heater = 5000 W

Total W: 4000 W + 1000 W + 3100 W + 5000 W = 13,100 W or 13.1 kW

Demand load: 13.1 kW × 0.50 = 6.55 kW, or 6550 watts

Once the demand load has been calculated, the proper feeder wire size can be chosen. For example, in the problem given here, the wire size must be AWG 8 to carry the wattage and span 100 feet. When determining the wire size needed from the meter base, which is the socket where the electric meter is attached at the yard pole, to the point where the wires break down to the individual structures, the same procedure is used by calculating the total connected load for all buildings and then using the table to determine wire size. Always increase service conductors by one size in consideration of future growth and increased power load.

Summary

The type and size of the wire used is critical to proper electrical installation. The wire, or conductor, directs the electrical current throughout the system, and these conductors must be of ample size to efficiently conduct the current. It is important to be able to calculate electrical usage and then use this information to determine wire size, while taking into account future demands and expansion.

Credits

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Lesson 4: Grounding and GFCI Protection

Electricity can be thought of as a living entity moving along a path through a circuit. However, if that circuit is interrupted, the electrical current still seeks a path to the earth. A ground wire is a safe method of establishing this necessary link by providing a path for the current. However, if a person uses a piece of equipment that is shorted out or improperly grounded, she or he may become the access point for grounding that the electrical current is seeking. Therefore, ground fault circuit interrupters are a crucial safety device, especially in damp areas.

Grounding and Its Importance

Grounding forms the connection between a piece of equipment or electrical appliance and the earth. It provides electricity an alternate path back to its source. The grounding point is typically established at or near the service entrance panel where electricity enters a structure. It may consist of a metal rod made of solid copper or copper-clad metal driven into the ground that is connected directly to the service panel with a ground wire. A grounding system may also consist of a grounding wire attached to an established galvanized metal water pipe.

The grounding system is connected to appliances and electrical equipment through a dedicated ground wire that is isolated from the power conductors in the electrical system. This wire may be connected either to the equipment directly or to the electrical outlet receptacle. The ground wire leads back to the ground connection at the service panel.

Grounding is important in the prevention of electrical shock. It provides a safety measure for channeling an electrical current that is out of the electrical circuit back to the earth at the source. This safety measure helps direct the charge away from humans or livestock who might come into contact with a shorted appliance or equipment.

NEC Requirements for Grounding

According to the NEC, grounding has three main purposes. First, it limits voltages in an electrical system due to lightning, line surges, or unintentional contact with higher voltage lines. Second, grounding helps stabilize voltages within the system. Finally, it provides a path to facilitate the operation of overcurrent devices.

NEC regulations state, "Premises wiring shall not be electrically connected to a supply system unless the latter contains, for any grounded conductor of the interior system, a corresponding conductor that is grounded." Basically, this statement means that the proper grounding rods must be in place and connected to the electrical system prior to making the electrical connection to the power source.

NEC regulations also describe the types of grounding systems allowed. The code states that the ground rod conductor is to be connected at the point where the electrical service enters the service panel. Also, all connections to the ground rod must be made at the service panel and the entrance point to the service panel, not on the individual circuits of the electrical system. The grounding electrode, or ground rod, should be as near as practical to the service entrance.

GFCIs

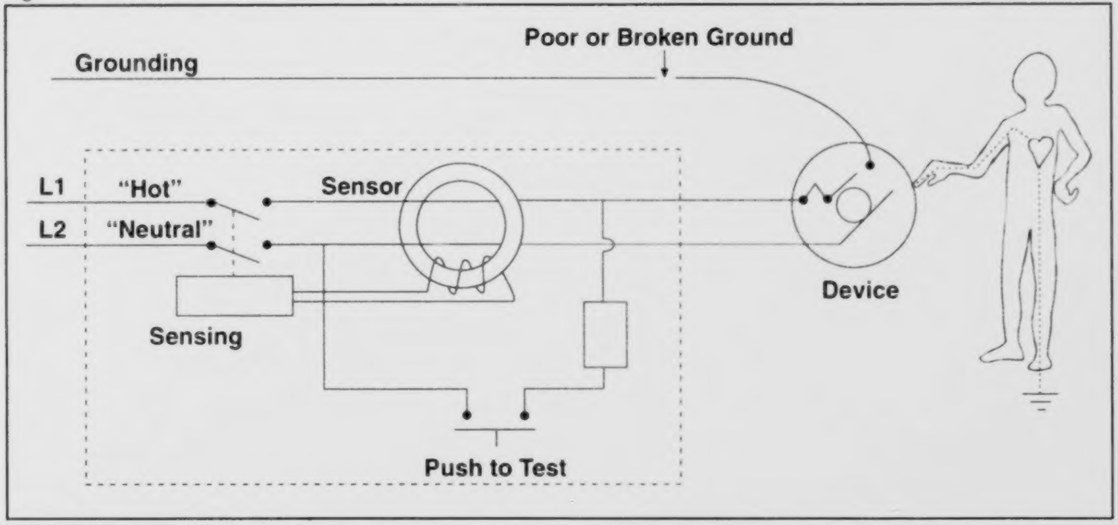
Putting faith in the grounding wire in a 3-wire electrical system is not always justified. A faulty ground wire could lead to a lethal shock. Therefore, using GFCIs is best in any situation where a potential shock hazard exists.

GFCI stands for ground fault circuit interrupter. A GFCI is a device that interrupts the circuit to any electrical device when a fault current, or a current which has moved out of its normal circuit, exceeds a predetermined level. The level is less than that required to operate the overcurrent protective device of the supply circuit. The primary function of a GFCI is to interrupt the flow of the current to prevent people and animals from being shocked.

A GFCI operates by monitoring the magnitude and time of electrical flow. The GFCI will interrupt abnormal electrical flows of 5/1000 amperes in 25/1000 of a second. These small amounts of amperage will not trip a regular electrical breaker or fuse.

GFCIs work by sensing imbalances in electrical circuits caused by shorts or other faults. When an imbalance occurs between the black "hot" wire and white "neutral" conductors, an uneven electrical load exists in the system, and a ground fault

Figure 4.1 - A GFCI at Work



current is present and seeking a return conductor to the source. A person or animal coming in contact with the fault current can provide this path, creating a shock hazard. The GFCI prevents shocks by stopping the electrical flow, as illustrated in Figure 4.1.

NEC Requirements for GFCIs

The NEC establishes where GFCIs should be installed. According to the NEC, GFCI protection is required for all outlet receptacles or any devices permanently wired into the electrical system that are installed in the locations listed.

- Bathrooms
- Garages and grade level portions of unfinished accessory buildings used for storage and work areas
- Outdoors
- Crawl spaces, where the crawl space is at or below ground level
- Unfinished basements and areas not intended as habitable rooms and limited to storage areas, work areas, and the like
- Kitchens, where the receptacles are installed to serve counter top surfaces
- Indoor or outdoor swimming pools
- Hot tubs
- Portable signs
- Any location using temporary power

Installation of GFCIs in Agriculture Structures

Four types of GFCI units are used in agriculture structures. They are the circuit breaker GFCI, the plug-in GFCI, the portable GFCI, and the outlet-type GFCI, all of which are pictured in Figure 4.2. The selection of one of these types for use in a particular structure depends on the requirements of the structure.

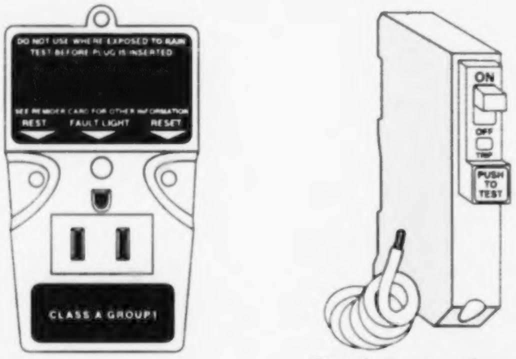
Circuit breaker GFCI - This type of GFCI is a fixed, permanently installed unit. It substitutes for a standard circuit breaker and controls the outlets within an entire circuit.

Plug-in GFCI - This device is designed for use in existing electrical systems that do not have GFCI devices installed. It plugs into a regular receptacle and protects only those appliances plugged into it.

Portable GFCI - The portable GFCI is similar to the plug-in type, except this device has an extension cord and is portable. It plugs into standard outlets. This GFCI is generally used for construction and short term circuit protection needs.

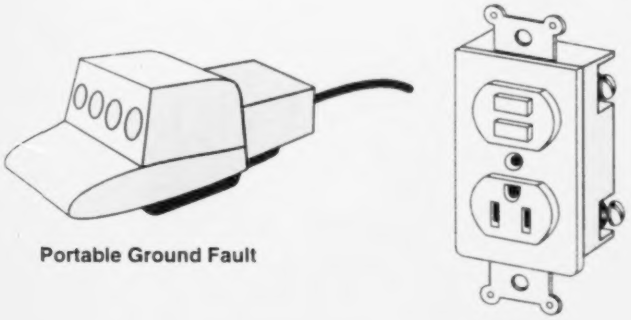
Outlet-type GFCI - As its name suggests, this GFCI is permanently mounted in an outlet box. It protects all the items plugged into it. The outlet-type GFCI is widely used in the construction of new buildings.

Figure 4.2 - Types of GFCIs


DO NOT USE WHERE EXPOSED TO RAIN
TEST BEFORE PLUG IS INSERTED
SEE REMINDER CARD FOR OTHER INFORMATION
REST
FAULT LIGHT
RESET
CLASS A GROUP1
ON
OFF
TRIP
PUSH TO TEST

Plug-In Ground Fault

Circuit Breaker Ground Fault



Portable Ground Fault

GFCI Outlet

Summary

The use of proper grounding and GFCIs in electrical systems is a critical component in construction for the home and farm. They provide a safety feature that protects humans and animals from electrical shock hazards and the electrical system from hazardous overloads. The requirements for this protection are addressed very specifically by the NEC, with regulations governing the application and use of grounding systems and GFCIs.

Credits

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Lesson 5: Lights, Outlets, Switches, and Circuit Protection

The primary intent of electrical wiring is to provide a convenient source of power for lighting and mechanical needs. These needs are met through the use of lighting systems, outlets, and switches. In planning the wiring of an agricultural structure, safety standards from the NEC and local rules and regulations must be followed.

Rules for Lighting Outlets in Agricultural Structures

Light fixtures must be appropriate for the environmental conditions that will be present in agricultural structures. Because of the nature of these structures, most will have wet or dusty environments. Therefore, specific measures must be taken when planning lighting outlets for these structures.

In wet areas, the NEC requires the use of a nonmetallic light fixture. These fixtures are to be made of nonconductive materials, such as porcelain, plastic, or rubber.

In areas where dust is a problem, such as a feed elevator or hay barn, dust-tight light fixtures are required. These fixtures prevent combustible materials from coming into contact with electrical connections that produce sparks.

Types of Lighting and Their Uses

Another important consideration in agricultural structures is the type of lighting to be used in a particular structure. To choose the best alternative, being familiar with the different types of light sources and the uses of each is necessary.

When discussing light sources such as light bulbs and fluorescent tubes, the term "lamp" is used. A lamp is a mechanism that produces light when an electrical current passes through it. Larger lamps will be more efficient and provide more light per watt of power used. For instance, three 60-watt lamps will provide 10 percent more light than five 40-watt lamps. The difference in wattage is an important consideration when planning the number of fixtures and the wire size to be used in a structure.

Numerous types of lighting are available. Incandescent lamps are the most familiar type. These lamps produce light when electricity moves through a wire filament that then glows at a white heat. The electricity heats the filament to more than 4,500 degrees Fahrenheit. The high temperature makes the filament give off light. This type of lamp is inefficient because much of the electricity used is changed to heat instead of light.

Another group of lamps are known as gaseous discharge lamps. These lamps pass an electric current through a gas enclosed under pressure in a tube or bulb. This process, referred to as electric discharge, produces light when the current moves through the gas particles. Two types of gaseous discharge lamps are available: low pressure gaseous discharge lamps, such as fluorescent lamps and low pressure sodium lamps, and high pressure gaseous discharge lamps, such as mercury vapor lamps, metal halide lamps, and high pressure sodium lamps.

Fluorescent lamps are made up of a glass tube that contains mercury vapor and argon gas under low pressure. Electricity flowing through the mercury vapor produces ultraviolet energy. This energy turns to visible light after striking the fluorescent coating on the inside of the tube; the coating is made up of phosphors, which are solid, nonmetallic chemical elements. Fluorescent lamps are used indoors. Because of advances in light quality, they can be used effectively for supplementary lighting in greenhouses. Fluorescent lamps are also made in a compact form for use in light sockets usually used for incandescent lamps.

Low pressure sodium lamps consist of two glass tubes, one inside the other. The inner tube contains solid sodium and a mixture of argon and neon gas. The outer tube provides a protective barrier for the lamp. When electricity moves through the inner tube, the gases react with the electricity to produce heat and an orange-colored light. As the sodium heats up, it vaporizes, and the lamp gives off a yellow light. These lamps are commonly used for street lights in towns.

Mercury vapor lamps also have a two-bulb configuration. The inner bulb is made of quartz and is called the arc tube. The arc tube contains mercury vapor at a high pressure, which allows it to produce visible light without the presence of phosphors. The light produced is greenish blue in color. These lamps have a longer life than other lamps of similar wattage. However, it may take 5 to 7 minutes for vapor pressure to build up and reach full brightness. Mercury vapor lamps are primarily used outdoors around farms and homes to light the outside of buildings.

Metal halide lamps contain compounds of metal and halogen with the same basic two-bulb design. These lamps produce more naturally colored light than do mercury vapor lamps. Metal halide lamps also have a long life and high light output. They are an excellent outdoor light source and have some indoor applications as well, such as supplementary lighting for greenhouses.

High pressure sodium lamps are similar to mercury vapor lamps. The difference is that the arc tube in the two-bulb configuration is made of aluminum oxide. The tube contains a solid mixture of sodium and mercury. These lamps produce an orange-white light and have a long life and very high light output. They are also used outside around homes and farms.

Rules for Convenience Outlets in Agricultural Structures

Convenience outlets are the points in the wiring system where electric power is used, such as electrical receptacles. They allow electrical appliances to be plugged in as necessary. A sufficient number of convenience outlets must therefore be included when planning agricultural structures.

Some basic guidelines are followed in determining the location of convenience outlets. First, outlets are installed where animals will not readily bump into them. Generally, they should be at least 5 feet above ground level anywhere livestock may be present. Also, they must be easily accessible. The outlets should be mounted between the studding or flush with the wall.

For agricultural structures, the correct type of convenience outlet must be used. They must be 20-amp duplex receptacles with a safety ground. A GFCI receptacle is preferable, especially in damp areas. Also, due to the environmental conditions in most agriculture structures, nonmetallic outlet boxes are necessary.

The number of convenience outlets installed within a structure depends on the amount of use the outlet will receive and the building type. For livestock buildings, 12 to 15 feet between outlets is recommended. In other structures, 8 to 10 feet of space is acceptable. A good rule of thumb when planning for convenience outlets is to install enough outlets so that extension cords will not have to be used on a regular basis.

Rules for Switches in Agricultural Structures

Switches are an important component in the electrification of agricultural structures. Switches control everything from lighting to motorized equipment. A major use of switches in agricultural structures is as safety disconnect devices. These switches shut off power to rows of receptacles on a single circuit or to motors when not in use.

The location of switches should be based on convenience and ease of access. Switches should be installed at elbow height in protected spots. If possible, the switch should be on the latch side of doors and on the traffic side of arches. When multiple doors provide access to a single room or bay, multiple switches are needed if the doors are farther than 10 feet apart.

Electrical Protection for Agricultural Structures

Because of the damp and corrosive environments typically found in agricultural structures, electrical protection is a priority in these buildings. Overcurrent devices and proper grounding procedures are a must. Branch circuits must contain adequate amperage-rated fuses or circuit breakers, which is calculated based on the anticipated use of the circuit. Proper grounding is also an important consideration. All noncurrent carrying devices, or ground wires connected to motor housings or to equipment, should be grounded. The system ground wire to the ground rod must be the same size as the wires carrying electrical current. For example, if the hot and neutral wires are AWG 12, then the ground wires must also be AWG 12.

General Recommendations for Branch Circuits

Branch circuits are the primary electrical connections for all uses within the agriculture structure. Therefore, it is very important to carefully plan the uses and load of these circuits.

The building must have enough circuits to carry out business efficiently. General purpose circuits that must be considered in planning are permanent lighting circuits, convenience outlets, any special lighting circuits like automatic on/off outdoor lights, and portable heater units. Also, the service entrance panel should have open circuit spaces for anticipated electrical expansion.

Some limitations apply to the use of branch circuits. Branch circuits should not operate at more than 2 percent voltage drop or use wire smaller than AWG 12. The electrical load is not to exceed 80 percent of the branch circuit rating, which is the rating of the branch fuse or circuit breaker. Fixed appliances must not be over 50 percent of the load if lighting is also included on the circuit.

Summary

When planning the electrical wiring of an agricultural structure, identifying the requirements for lighting, outlets, and switches for that building is crucial. Using materials designed for the typical uses and environmental conditions of these structures is also important. As in any structure, electrical protection and good circuit design are necessary. Careful planning is required to design a system that will meet current and future demands.

Credits

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Missouri Department of Natural Resources. "Division of Energy." http://www.dnr.state.mo.us/de (25 Jan. 1999).

Richter, H.P., and W.C. Schwann. *Wiring Simplified.* 38th ed. Somerset, Wis.: Park Publishing, Inc., 1996.

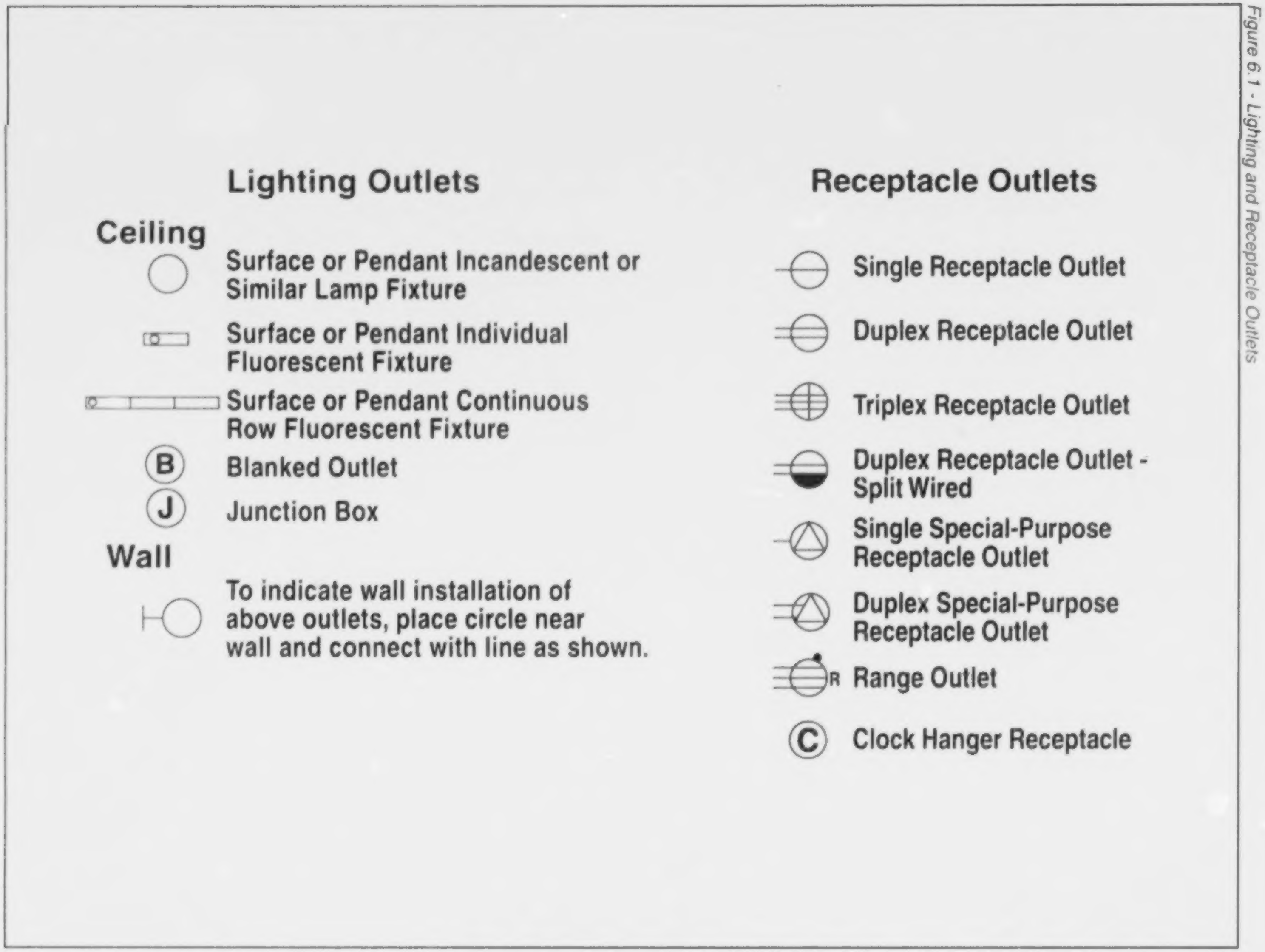

Lighting Outlets
Ceiling
Surface or Pendant Incandescent or Similar Lamp Fixture
Surface or Pendant Individual Fluorescent Fixture
Surface or Pendant Continuous Row Fluorescent Fixture
B
Blanked Outlet
J
Junction Box
Wall
To indicate wall installation of above outlets, place circle near wall and connect with line as shown.
Receptacle Outlets
Single Receptacle Outlet
Duplex Receptacle Outlet
Triplex Receptacle Outlet
Duplex Receptacle Outlet - Split Wired
Single Special-Purpose Receptacle Outlet
Duplex Special-Purpose Receptacle Outlet
R
Range Outlet
C
Clock Hanger Receptacle

Figure 6.1 - Lighting and Receptacle Outlets

Agricultural Structures, V-22

Lesson 6: Electrical Symbols in Wiring Plans

The use of symbols in wiring plans is a standardized method of identifying the location of electrical components. Familiarity with these symbols is necessary to read plans and correctly install electrical systems.

Lighting, Receptacle, and Switch Outlets

The symbols in Figure 6.1 are those most commonly used to identify electrical lighting outlets. In describing light fixtures, the symbols identify those fixtures that are surface mounted into or onto the wall or ceiling and those that hang from hardware in the ceiling. Blanked outlets are outlets with cover plates placed over the boxes. They have wires in the box which may be used for future lighting or power needs. Junction boxes are those electrical boxes in which circuit wires are routed to different locations in the structure.

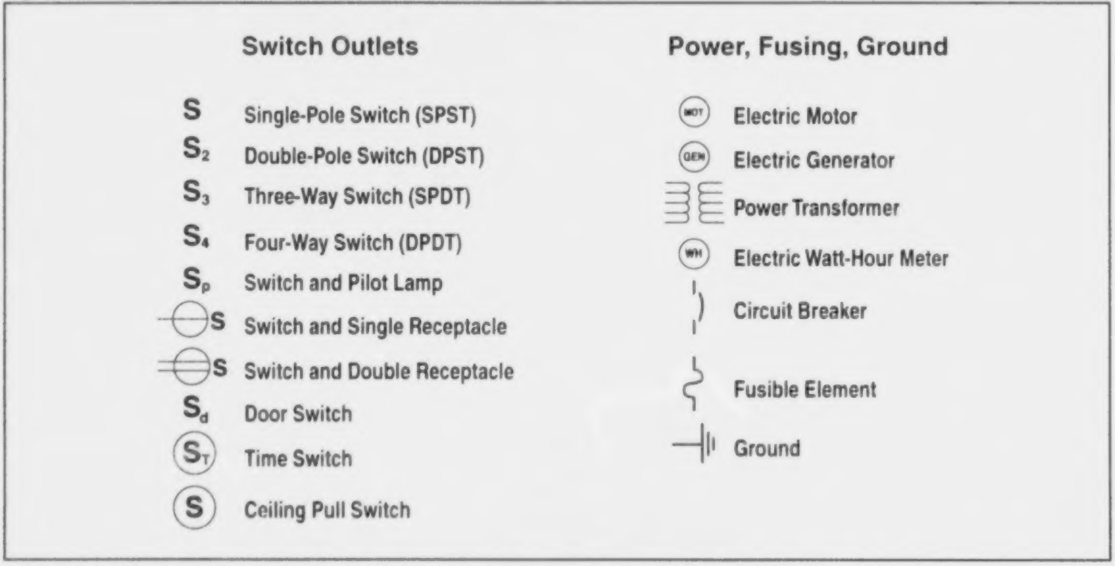
Symbols are also used to indicate the different types of receptacle outlets commonly included in agricultural structures. These symbols are shown in Figure 6.1. Receptacle outlets include standard outlets with one, two (duplex), or three (triplex) outlets per box and specialized receptacle outlets. Letters next to the symbol for specialized outlets indicate their purpose; for example, DW would stand for dishwasher. Some specialized outlets, such as special purpose outlets that have modified plug openings for specific applications, are diagramed for 110-volt systems. Range outlets describe 220-volt receptacles. Clock hanger receptacles are specialized low amperage outlets designed to be used with electric clocks.

Special symbols are used to represent switch outlets as well. Switch symbols note the number of poles, or terminal connection points on the switch, and if the switch connections are for three- or four-way light systems with multiple switches. Other specialized switches identified are those with a lamp on the switch, switches with outlet receptacles included at the location, automatic door switches, switches that have built-in timers to turn them on or off, and ceiling pull switches. Figure 6.2 shows the symbols for these switches.

Power, Fusing, and Grounding

Symbols are also used to identify electrical power sources, circuit overload protection devices, and grounding sites of the agricultural structure, as shown in Figure 6.2. Those power sources typically identified for agricultural purposes are electric motors installed in the system, electric generators, and power transformers for power conversion, as in 3-phase electric power systems. The locations of watt-hour meters, grounding sites, and circuit breakers and fuses in branch circuits are all indicated by special symbols.

Figure 6.2 - Switch Outlet, Power, Fusing, and Grounding Symbols


Switch Outlets
S Single-Pole Switch (SPST)
S2 Double-Pole Switch (DPST)
S3 Three-Way Switch (SPDT)
S4 Four-Way Switch (DPDT)
Sp Switch and Pilot Lamp
S Switch and Single Receptacle
S Switch and Double Receptacle
Sd Door Switch
ST Time Switch
S Ceiling Pull Switch
Power, Fusing, Ground
MOT Electric Motor
GEN Electric Generator
Power Transformer
WH Electric Watt-Hour Meter
Circuit Breaker
Fusible Element
Ground

Panelboards, Switchboards, and Related Equipment

Symbols related to the power and fusing systems identify panelboards at the service entrance and switchboards and switch controllers for electrical motor operations. These symbols are illustrated in Figure 6.3.

Remote Control Stations for Motors or Other Equipment

Other symbols related to the operation of motors are shown in Figure 6.3. Push-button stations are electric switches that use a button-type on/off switch to control electric motors. Remote control stations are those locations where electric motor switches are in a location that is not directly attached to the motor that the switch operates. Float, limit, and pneumatic switches are all specialized variations of remote switches. Thermostat switches are switches used to control electric motors or other electric devices; they are activated by changes in air temperature.

Miscellaneous Connections

Because of the environmental conditions present in most agricultural structures, specialized electrical equipment is installed. This equipment is identified using a special group of electrical symbols. Figure 6.3 shows these symbols. For example, some of the symbols identify electrical fixtures that are designed to provide protection from weather, water, dust, flammable vapors, and explosions caused by combustible materials. They also indicate grounded (GFCI) and recessed devices.

Summary

In order to successfully wire a building, being able to read electrical wiring diagrams is a must. The symbols shown in this lesson are those commonly used in agricultural structures. Familiarity with these symbols will help in correctly installing electrical wiring.

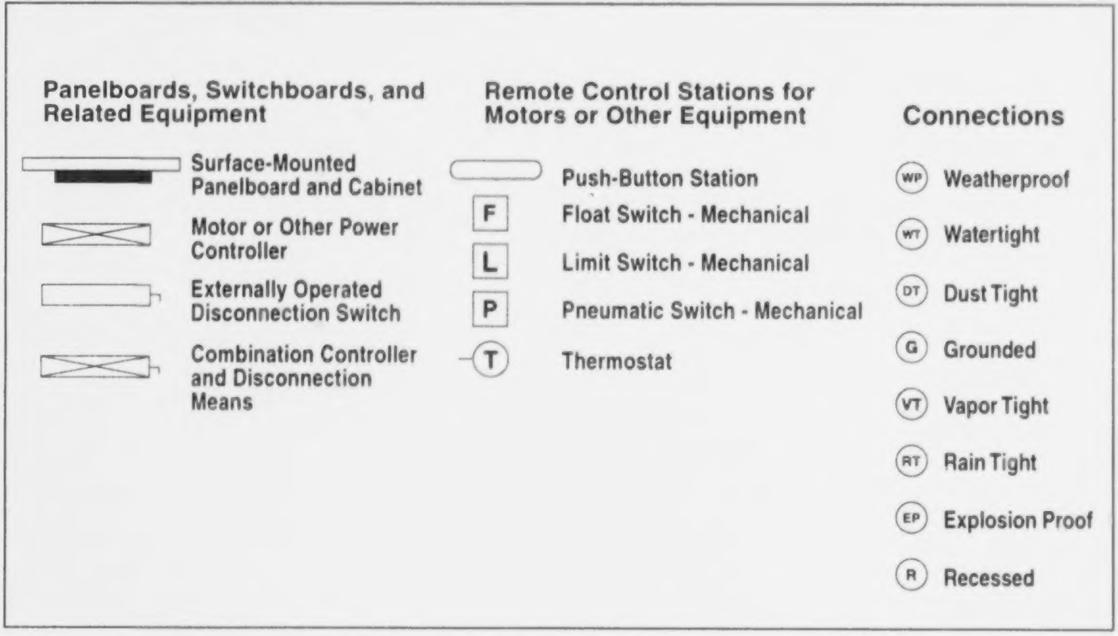
Credits

Cooper, Elmer L. *Agriculture Mechanics: Fundamentals and Applications*. 2nd ed. Albany: Delmar, 1996.

Holzman, H.N. *Modern Residential Wiring*. South Holland, Ill.: Goodheart-Willcox Company, Inc., 1986.

Phipps, Lloyd J., and Carl L. Reynolds. *Mechanics in Agriculture*. 4th ed. Danville: Interstate Publishers, Inc., 1990.

Figure 6.3 - Electrical Symbols


Panelboards, Switchboards, and Related Equipment
Surface-Mounted Panelboard and Cabinet
Motor or Other Power Controller
Externally Operated Disconnection Switch
Combination Controller and Disconnection Means
Remote Control Stations for Motors or Other Equipment
Push-Button Station
F
Float Switch - Mechanical
L
Limit Switch - Mechanical
P
Pneumatic Switch - Mechanical
T
Thermostat
Connections
WP
Weatherproof
WT
Watertight
DT
Dust Tight
G
Grounded
VT
Vapor Tight
RT
Rain Tight
EP
Explosion Proof
R
Recessed

Lesson 7: Running Electrical Wiring

The electrical service pole is the central hub for power distribution on an agricultural operation. The installations made at the yard pole, the main service entrance, and the meter should be made by an electrical contractor or the power company. However, understanding the configuration at the pole is important in completing further wiring installations or making repairs to the system.

The Configuration at the Pole

Three wires bring electricity in from the power company to an agricultural operation. These wires include two hot wires and one neutral wire. The wires are connected to the meter base at the yard pole, and power is distributed to the different structures from the pole. The grouping of the wires at the pole is called the stack.

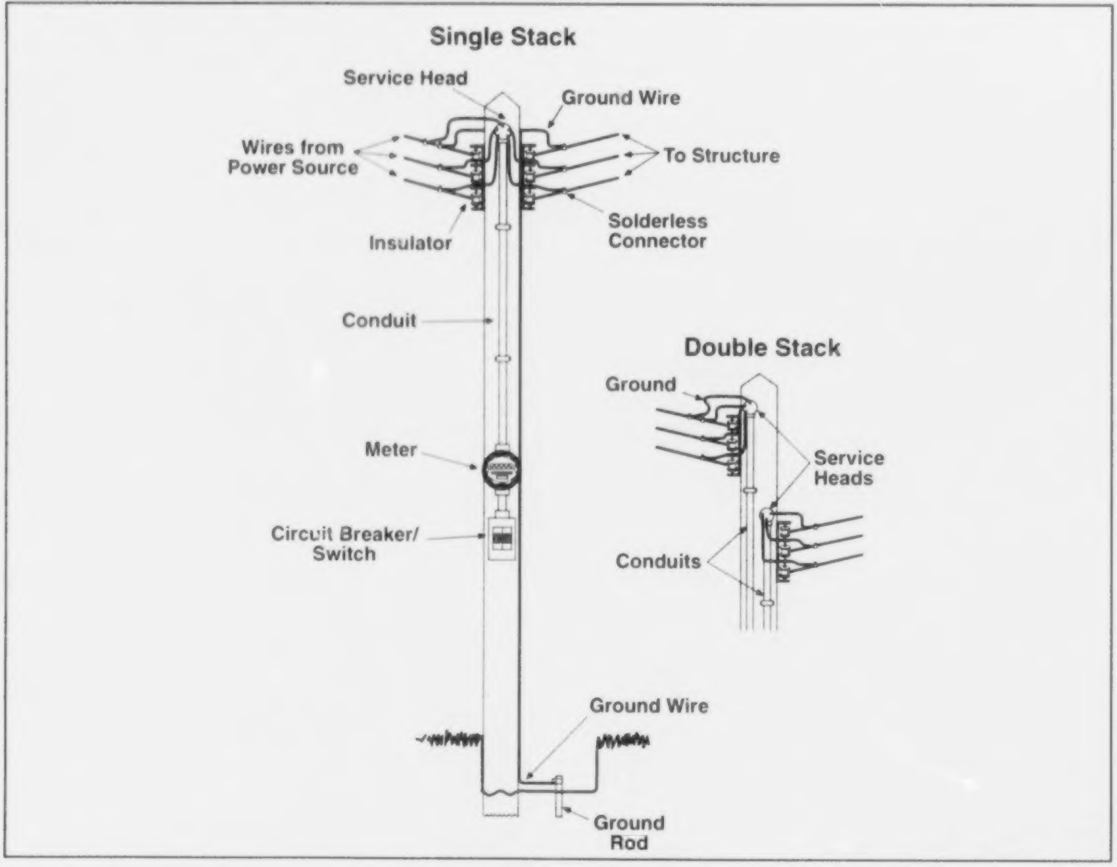
The stack may have either a single stack or a double stack, as shown in Figure 7.1. In single stacking, the wires that travel into the meter from the power company and those wires traveling out to individual structures are both contained within a single conduit attached to the pole.

In double stacking, the supply wires coming in from the power company use a separate conduit from the wires that lead out to the individual structures. This configuration is used for both overhead and underground wiring installations. Double stacking is utilized when a large number of structures are being served by one meter.

A separate ground wire that is connected to the neutral wires runs along the outside of the conduit to a ground rod. This form of electrical grounding is best for handling lightning. The ground wire should be AWG 6 in size.

Connections at the pole are relatively simple. All of the wires carrying power in to or out from the

Figure 7.1 - Stack Configuration at the Pole


Single Stack
Service Head
Ground Wire
Wires from Power Source
To Structure
Insulator
Solderless Connector
Conduit
Meter
Circuit Breaker/ Switch
Ground Wire
Ground Rod
Double Stack
Ground
Service Heads
Conduits

pole are connected directly to the pole with insulators. These insulators should be heavy enough to withstand weather conditions and are typically made of ceramic. Two racks of insulators with three insulators per rack are required, one rack for incoming wires and the other for outgoing wires. The insulators should be anchored with heavy lag screws and at least one through bolt inserted through the pole for added strength. Insulators are not needed for underground wiring because the wires are fed through a buried conduit.

Feeder wires are used to carry power to the meter base. They are attached to the supply wires with solderless connectors. Once the splice is made, these connectors should be taped to provide insulation. The feeder wires then enter the conduit through the service head, which is a special fitting that is angled to keep water from entering the conduit. The wires run down the conduit and then attach directly to meter base.

Short feeder wires are attached from the meter base to the main power disconnect switches at the pole. A disconnect switch should be available for all individual electrical service systems to which power is supplied. For individual electrical systems, two structures may be operated off of one.

The size of the feeder and supply wires traveling from the disconnect switches to the structures will be determined by each structure's demand load. The supply wires are either attached to the pole with insulators or buried underground.

Installing the Service Entrance

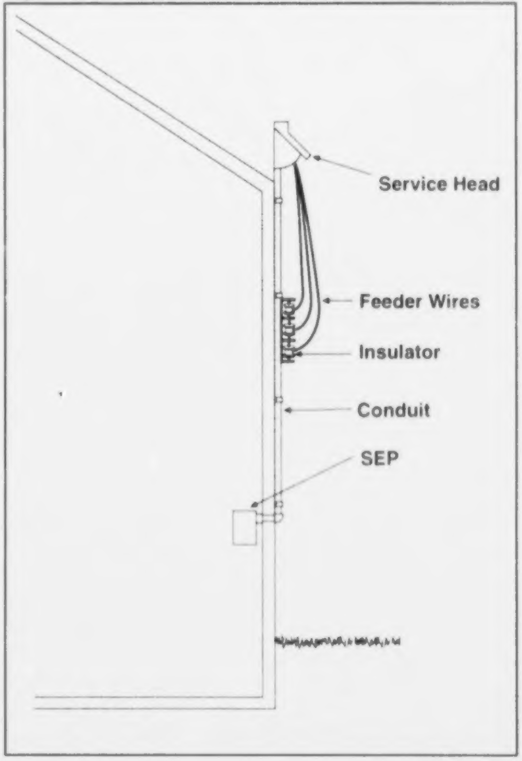
Once the configuration at the pole is in place and the amperages determined for the individual structures, the service entrance needs to be installed. NEC regulations determine the size and type of wire used at the service entrance. According to the NEC, AWG 8 wire is allowed if up to two two-wire circuits are being installed, and AWG 6 is allowed if up to five two-wire circuits are being installed. For bigger systems, amperage calculations and wire size tables are needed to determine the proper wire size.

The type of power service required in the structure will determine if the service entrance will have a two-wire or three-wire type service. A two-wire system has 110 volts available for use, which is acceptable for small sheds or buildings that will have only lights or outlet receptacles in use. A three-wire system has both 110 and 220 volts available for use within the structure. It can provide electricity for equipment requiring 220 volts, such as a welder.

The location of the service entrance is an important consideration. The location of the SEP should be determined prior to running wires from the power pole. NEC guidelines indicate that the SEP should be as close as practical to the point where wires enter the building. If possible, the service box should be near equipment that requires higher 220-volt electrical loads to reduce expensive wire runs and voltage drop. The SEP should be installed in a location that is easily accessible.

The wire connections at the building are similar to those at the yard pole. Insulators are connected to the structure for overhead runs of wire. The feeder wires connect to main wires and then run into the service head, through the conduit, and into the service entrance panel (SEP). Figure 7.2 illustrates the service entrance.

Figure 7.2 - Installation of the Service Entrance



Using Branch Circuits

When planning an electrical system, it is important to consider how many branch circuits will be necessary within a structure. The type of structure and its use will be determine the number of circuits needed. Small sheds with lighting need only two branch circuits. The second circuit allows for backup lights if one circuit blows. Larger structures, such as shops and barns, typically need 110/220-volt service because they often have equipment that requires 220 volts. Each 220-volt outlet requires a separate circuit, which is made by combining two 110-volt circuits at the service entrance panel. The number of circuits will vary depending on the number of electrical systems and the number and type of appliances used.

When determining the number of circuits needed, careful calculations of the wattage used by all electrical components are necessary. A good rule of thumb is to add additional circuits and break up the system to avoid overload problems. Planning for expansion is also important when installing the SEP and calculating the need for branch circuits.

Wiring a Barn

Most agricultural structures have special characteristics that must be considered when planning electrical wiring. One of the biggest considerations for barns is their environmental conditions. Barns naturally have damp and corrosive environments and tend to lack proper ventilation. NCM or UF cable is required along with nonmetallic junction boxes that resist moisture.

Another factor to consider is mechanical damage, or damage caused by crushing, pinching, or crimping conductors when livestock, tools or equipment inadvertently come in contact with wires. Running wires along the sides of beams and joists to where fixtures are located provides protection. Wires are also run in protective conduits to prevent mechanical damage.

When planning for electricity in the barn, providing lighting, switches, and receptacles is important. Plenty of lighting should be included throughout the barn. Switches should be easily accessible and mounted at elbow height. Receptacles should be dust tight, watertight, and corrosion resistant. Installing GFCI outlets is a good idea.

Livestock considerations are also a factor in planning electrical wiring. Lights, outlets, and switches should be out of the reach of livestock. This practice will prevent damage to equipment, fire hazards, and shock hazards to animals.

Wiring a Hay Barn

For hay barns, dust is an important consideration. The dust produced by hay is highly flammable, so precautions must be taken to prevent electrical sparks from coming in contact with the dust. Wires must be enclosed in conduits or within a wall covered with sheathing. Vapor proof fixtures seal out dust from electrical connections. Lighting fixtures should minimize the entrance of dust as well as foreign matter, moisture, and corrosive materials into the exposed wiring areas. In addition, fixtures exposed to physical damage must be protected by a guard, while fixtures exposed to water must have watertight protective coverings.

Selecting Switches and Receptacles

Choosing proper switches and receptacles is an important consideration when planning the wiring of any agricultural structure. The NEC requires that switches, circuit breakers, motor controllers, fuses, push buttons, relays and similar devices be protected from environmental and physical damage. These components should have weatherproof, corrosion resistant enclosures designed to minimize the entrance of dust, water, and corrosive elements. Switches and receptacles designed for outdoor use may be useful because these components tend to be durable and provide protection from environmental conditions.

Summary

Wiring for agricultural operations is in some ways very different than other wiring situations. For example, the use of a centrally located yard pole that acts as a power hub for all the surrounding structures is unique to agriculture. Only trained professionals should connect the electrical service at the pole and meter base and at the main service entrance.

Wiring for branch circuits and electrical fixtures is less specialized, however. Carefully planning the wiring for a structure is important. In particular, due to the nature of agriculture structures, wiring and fixtures such as lights, switches, and receptacles should have adequate protection from their environment.

Credits

Holzman, H.N. *Modern Residential Wiring.* South Holland, Ill.: Goodheart-Willcox Company, Inc., 1986.

Richter, H.P., and W. C. Schwann. *Wiring Simplified.* 38th ed. Somerset, Wis.: Park Publishing, Inc., 1996.

Lesson 8: Connecting to the SEP

Once the wiring is in place in an agricultural structure, the next step is connecting the circuits to the service entrance panel. The SEP is the main distribution point for electrical power in the structure. Within the SEP, individual branch circuits link to the incoming power source, thus providing electrical power to the entire system.

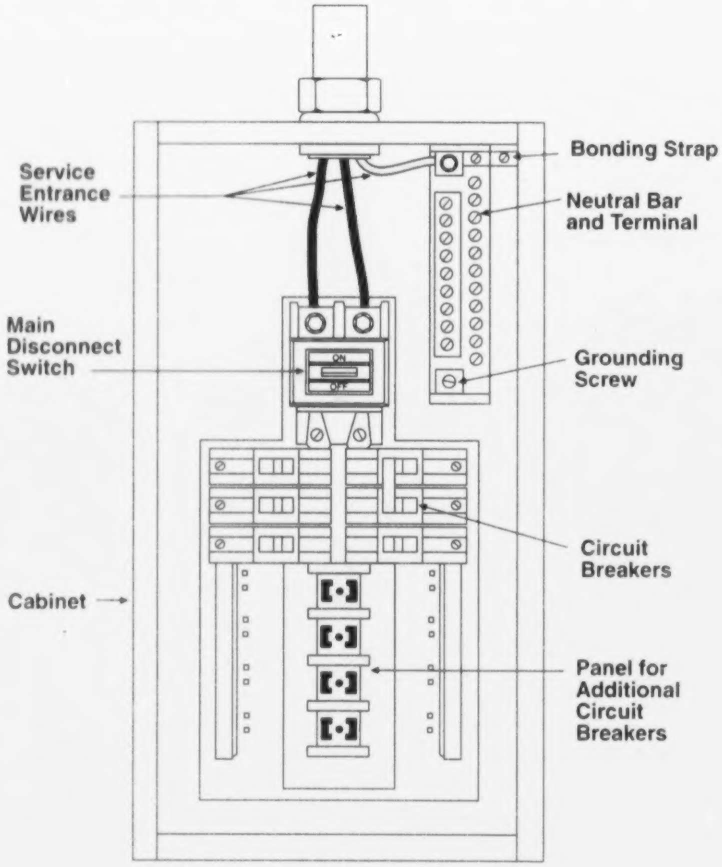
SEP Parts

The parts of the SEP are housed within the service entrance cabinet, as shown in Figure 8.1. The main disconnect switch is a large amperage breaker used to disconnect the power coming into the structure from the individual circuits. This safety device can be shut off for electrical repairs or emergencies.

Also within the box is a panel with banks, or rows, of sockets designed to accept either circuit breakers or fuses. Generally, some of these sockets will remain open for expansion purposes. The circuit breakers or fuses provide overcurrent protection for the circuits.

Other components of the SEP ground the system. The neutral bar is a specialized bar with terminal screws placed in it to make connections between neutral wires and ground wires. The grounding screw is the point where the ground wire connects to the neutral bar to ground the SEP cabinet. The cabinet can also be grounded using a flexible bonding strap.

Figure 8.1 - SEP Parts


Service Entrance Wires
Main Disconnect Switch
Cabinet
Bonding Strap
Neutral Bar and Terminal
Grounding Screw
Circuit Breakers
Panel for Additional Circuit Breakers
ON
OFF

Good Wiring Practices

When making the connections in the SEP, following proper wiring procedures is important. One of the biggest concerns involving the SEP is the buildup of heat and the overheating of wires within the panel. Several wiring procedures can reduce the likelihood of overheating. One way to reduce heat buildup is by wiring neatly and keeping wiring orderly within the cabinet. The SEP cabinet should not have excessive wire in it, so wire runs in the SEP should be kept as straight and direct as possible. Wires should not be bent during wiring, because the constriction of wires can cause insulation damage as well as overheating.

Other good practices should be followed as well. Tight connections without excessive bare wire showing should be made at the terminal screws. The neutral bar should be placed in a convenient location in the SEP box to make direct wire runs easier. Wires should be cut to the exact length necessary, removing any excess wire from the box.

Connecting Service Entrance Conductors to the SEP

Service entrance conductors must be connected properly in the SEP. Typically, for 120/240-volt systems, three wires enter the SEP in a bundle of wire. They include two 120-volt hot conductors and one neutral conductor. Two wires make up 120-volt systems, one hot wire and one neutral wire.

The most important thing to do before connecting any wires is to check to make sure that the power is shut off. When the power is off, the two hot conductors, which consist of two black wires or one black and one red wire, are connected to the main disconnect switch. The conductors should be cut to the proper length so no excessive wire is in the cabinet. Then enough insulation is stripped off to make a good connection. The bare ends of the wire are inserted into the connectors on the main disconnect, and the holding screws are tightened securely onto the wires. Using the same procedures, the neutral wire is attached to the neutral bar. The SEP cabinet is then grounded by attaching either the flexible bonding strap or the ground wire to the grounding screw.

Installing the Ground System

Grounding involves connecting a ground wire from the neutral bar in the SEP to a grounding electrode or a ground system. The ground system, in which grounding electrodes are connected together, is the preferred method of grounding. A ground system is pictured in Figure 8.2.

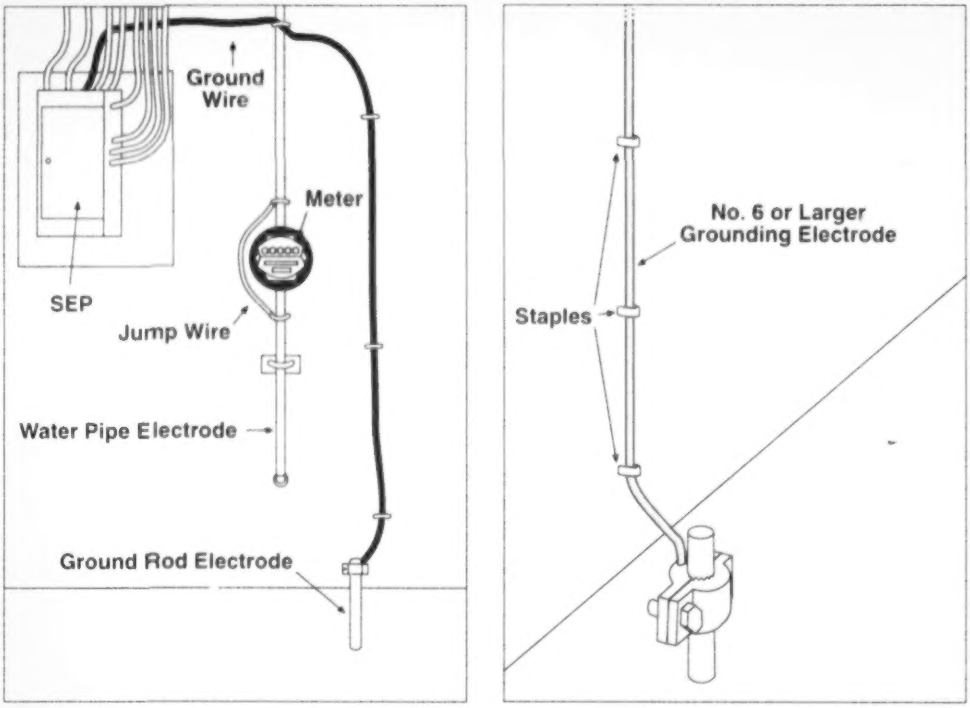
Several different types of electrodes may make up ground systems. One alternative is a buried metal water pipe 10 feet or more in length, which must be supplemented by at least one other electrode. The grounded metal frame of the structure can also serve as an electrode. Another type of electrode consists of a concrete-enclosed electrode composed of either 20 or more feet of ½-inch reinforced steel or AWG 4 copper wire. The steel or wire is placed inside at least 2 inches of concrete located near the bottom of the foundation. It runs through the concrete into the ground, coming into direct contact with the earth. A buried AWG 2 or bigger wire that encircles the entire structure can also be a grounding electrode in a grounding system.

If none of these options for the ground system are available, a grounding electrode is used. Grounding electrodes can consist of underground metal piping or buried metal tanks, a ½-inch copper rod or ⅝-inch metal or copper-clad rod, a ¾-inch galvanized steel pipe, or a buried metal plate at least 2 square feet in diameter.

The size of the ground wire is another important element of the ground system. The NEC has set the following guidelines for grounding conductors. If the service entrance conductor is AWG 2 or smaller, AWG 6 or 8 wire should be used for grounding. If the service entrance conductor is AWG 1 or 0, AWG 6 is the minimum size permitted for the ground wire. If the service entrance conductor is AWG 2/0 or 3/0, the ground wire should be a minimum of AWG 4. If wire larger than AWG 3/0 is used at the service entrance, AWG 2 must be used for the ground connection.

The ground wire must be installed properly. The wire is fastened to the surface over which it runs using special staples. The wire should be installed in a location that will minimize physical damage. Protection is typically provided by either tucking the ground wire behind the service conduit entering the structure or running the wire along

Figure 8.2 - Ground System



wall studs. If AWG 8 or smaller wire is used for grounding, it must be protected with a conduit. However, larger wire sizes do not need this protection.

Selecting and Sizing Circuit Protection

As discussed in Lesson 2, the diameter of the conductors used in the wiring determines the maximum safe amperages. If more than the maximum amperage flows through the conductor, the temperature of the wire will increase. The heat can damage insulation and cause fires. To prevent this from happening, either fuses or circuit breakers are installed in the SEP in each branch circuit.

When planning the installation of the SEP, determining whether fuses or circuit breakers will be used is important. Most modern structures use circuit breakers because they are more convenient and easy to use. Other factors considered when selecting overcurrent devices are the wire size and amperage ratings, the electrical devices operated on the circuit, and the demand load of the circuit.

Correctly sized circuit protection devices must be installed. The main disconnect breaker determines the total electrical capacity of the SEP. These breakers are rated at 30, 40, 50, 60, 70, 90, 100, 125, 175, and 200 amps, with larger breakers available for industry purposes. The size of the service breaker will determine how much power is available; a 50-amp service breaker with 240 volts of power coming in will supply 12,000 (50 x 240) watts of power to the system.

Fuses and circuit breakers also have amperage ratings. Beginning at 15 amps, they increase by 5-amp increments up to 50 amps. Any overcurrent device used must have a amperage rating equal to or less than the rating for the conductor. For instance, an AWG 12 wire with an amperage of 20 amps would require an overcurrent device rated at 20 amps or less.

Connecting 120-Volt Branch Circuits to the SEP

Once the service wires have been connected to the SEP, the branch circuits and circuit breakers can be installed and connected. Planning the location of each circuit before beginning the installation is important. The first step in making the connections is to connect the neutral and ground circuit wires from the branch circuit to the neutral bar. These connections are made by stripping off enough insulation from the wires to make good contact with the neutral bar and then placing each wire under a different screw on the neutral bar, as shown in Figure 8.3. The screws should be tightened firmly. Next, the hot wire is attached by stripping off the insulation of the black wire and inserting the wire under the terminal screw of the circuit breaker, which should be screwed tight. Finally, the circuit breaker is inserted into the slot in the SEP board.

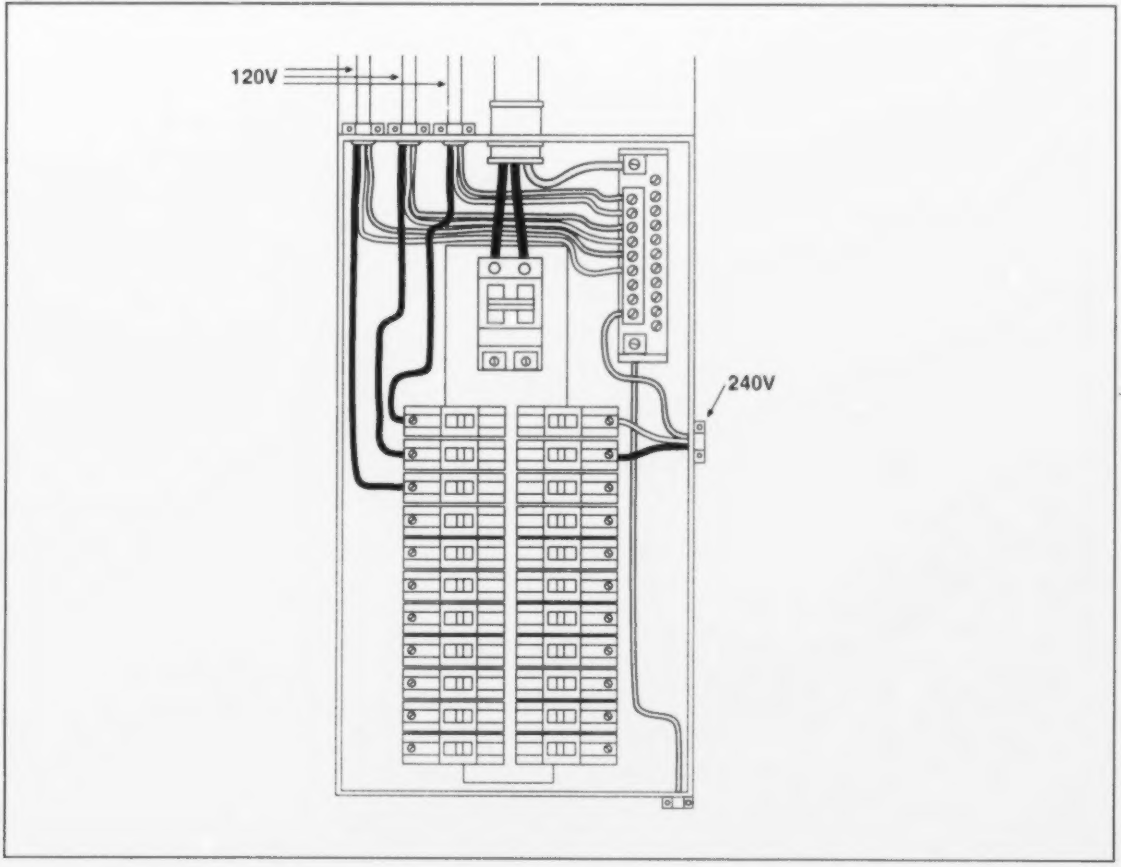
Connecting 240-Volt Individual Circuits to the SEP

Larger circuits that carry 240 volts utilize a special double-pole circuit breaker in the SEP. It has two connections because the circuit has two hot wires. To connect the wires, the black circuit wire is first connected to one terminal screw of the double-pole breaker. The white circuit wire is then connected to the other terminal screw. Finally, the ground wire is attached to the neutral bar. Figure 8.3 illustrates this type of circuit.

Three-Phase Power

Another type of power supplied to agricultural structures is three-phase power, a form of alternating current. Single-phase alternating current provides power in a wave-like pattern, with periods of high amperage and low amperage as the current changes the direction of flow. Three-phase AC power utilizes three hot wires, each

Figure 8.3 - Wired 120/240 V Panel



carrying electrical current at different stages of alternation; each wire peaks in amperage at a slightly different point in time. By synchronizing the wave patterns of the three hot wires, a more consistent amperage is achieved.

Three-phase power may be useful in some situations. Three-phase motors may be less expensive than single phase motors with the same horsepower. Three-phase power can also operate larger motors than standard single-phase power and will power those motors more efficiently.

Some limiting factors affect the use of three-phase power. The cost of three-phase power is higher than that for single-phase power because of the additional hot wire required. The power company must install additional transformers, which are devices used by power companies to raise or lower the voltage of alternating current for use in the home or business. A more expensive meter is needed to monitor power usage.

If three-phase power is desirable, it may be installed if it is not already available, or a phase converter may be used. A phase converter is a specialized device that allows a three-phase motor to operate using single-phase power. Phase converters can be very expensive, so an analysis of power needs should be conducted to determine if the investment is necessary.

Three-phase power is different from single-phase power in terms of wiring. Typically, the wire sizes are similar, but virtually all three-phase power circuits are hard wired, which means that three-phase outlets do not exist. Machines that require three-phase power do not have a plug at the end of a cable. Instead, the wires coming out of the machine are connected directly to the wires at the breaker box. This practice prevents single-phase machines from being plugged into three-phase outlets, which would burn out the motor.

Summary

The SEP is the point from which power is routed throughout an agricultural structure. A properly installed SEP is critical to providing an efficient electrical system for the structure. Wiring the service entrance conductors and the circuits properly is vital. The SEP should also be grounded correctly. The SEP houses individual circuit protection in the form of overcurrent devices, which should be carefully selected and installed to meet the needs of the structure. If three-phase power is to be used, it should also be installed with care.

Credits

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Holzman, H.N. *Modern Residential Wiring.* South Holland, Ill.: Goodheart-Willcox Company, Inc., 1986.

Richter, H.P., and W. C. Schwann. *Wiring Simplified.* 38th ed. Somerset, Wis.: Park Publishing, Inc., 1996.

Lesson 9: Running Wire from the SEP

Once the electrical power has been directed from the yard pole into the service entrance panel, it is time to consider the proper procedures for wiring the agricultural structure and connecting power to the switches, lights, and convenience outlets. When initially planning the wiring of the structure, determining the number and type of circuits that will be established in the building is important.

Location of the SEP

As discussed in Lesson 6, the NEC requires that the SEP be as close as practical to the point where the wires enter the building. It should also be located near equipment that has a high electrical draw, such as water heaters or large motorized equipment. This practice will reduce the costs of wiring by shortening the length of the run for larger wire sizes. It will also reduce voltage drop.

The SEP should be in an easily accessible location for three reasons. In an emergency, someone must be able to shut off power immediately. Also, ease of access to the panel is necessary if fuses blow or breakers are tripped. Finally, an easily accessible panel makes it easier to add circuits to the system.

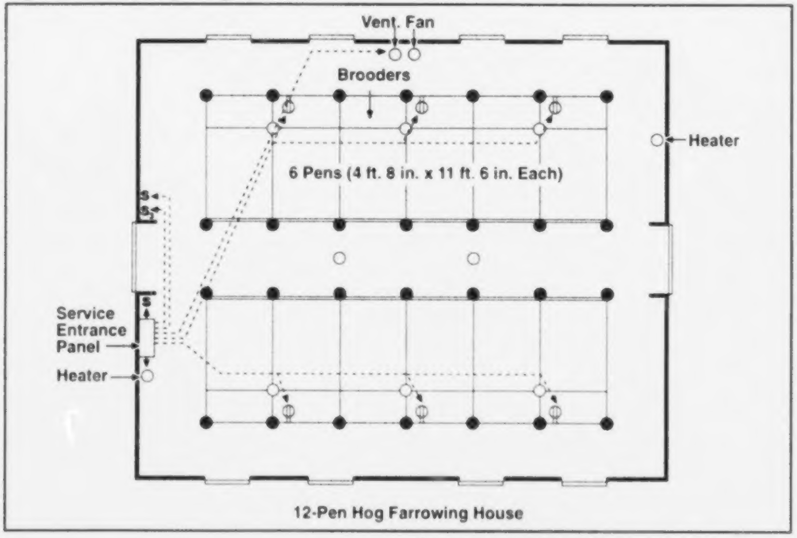
Determining the Route of Each Circuit

When the SEP is in place, the route of individual branch circuits can be planned. Because many different circuits may be used to control different outlets, lights, and pieces of equipment, carefully planning the path of each electrical circuit is important.

Two types of electrical circuits are considered when making a wiring plan. General circuits are those circuits carrying 110-volt current and normally containing more than one electrical device. Individual electrical circuits carry 220 volts of current and typically operate a single piece of equipment. Determining which type of circuit will be used and where the electrical devices will be placed within the structure is necessary. Remember, the placement of the SEP is partially determined by where the individual circuits with their heavier electrical loads will be placed.

The next consideration is which outlets will be connected to which circuit at the service entrance panel. A good rule of thumb is to avoid placing all the light fixtures in the same room or building on one circuit. With them all on a single circuit, if the overcurrent device that controls the lighting is triggered, the building or room will be in the dark, which may make it difficult to correct the problem. The amount of electrical load placed on convenience outlets will determine their circuit needs. If the outlets in a room or building will have low usage, with one to two outlets used at any given time, these outlets may be placed on a single circuit. If more than two outlets will be used at once or equipment with a high electrical draw will be used on a regular basis, the outlets should be split up on different circuits. Detailed planning can help avoid problems with blown circuits.

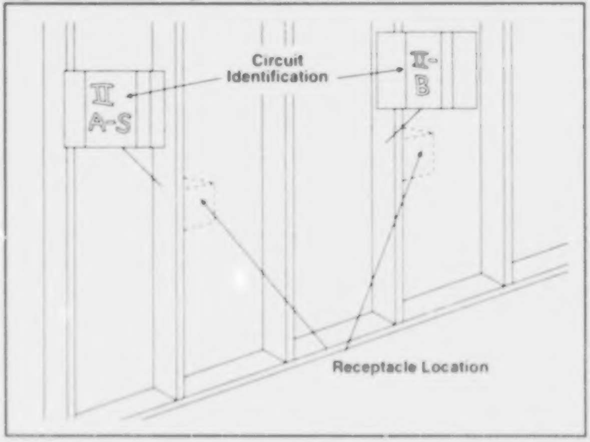
Figure 9.1 - Wiring Diagram


Vent. Fan
Brooders
Heater
6 Pens (4 ft. 8 in. x 11 ft. 6 in. Each)
S
S
S
Service Entrance Panel
Heater
12-Pen Hog Farrowing House

A wiring diagram (Figure 9.1) is useful when planning where branch circuits will run and what electrical devices will be connected to them. On the diagram, the entry point is marked first. The entry point is the point on the circuit where the wire attaches to the first electrical device on the circuit. The next step is adding up the number of devices on the circuit and making sure sufficient amperage can be supplied. This process is repeated for each circuit.

Next, outlet boxes for lights and receptacles are physically mounted at each location. They are labeled on the diagram and within the structure for easy reference. A code system based on the circuit used makes it easy to connect electrical wiring to the appropriate circuits and outlets. Figure 9.2 shows an example of circuit identification. One coding method involves using Roman numerals (I, II, III, etc) for the individual circuit line. Letters (A, B, C, etc.) designate the different outlet boxes. Switches are labeled with an S; if three-way switches are used, they are labeled S1 and S2. All outlet boxes and switches should be labeled prior to installing any wire for the branch circuits.

Figure 9.2 - Labeling Receptacles



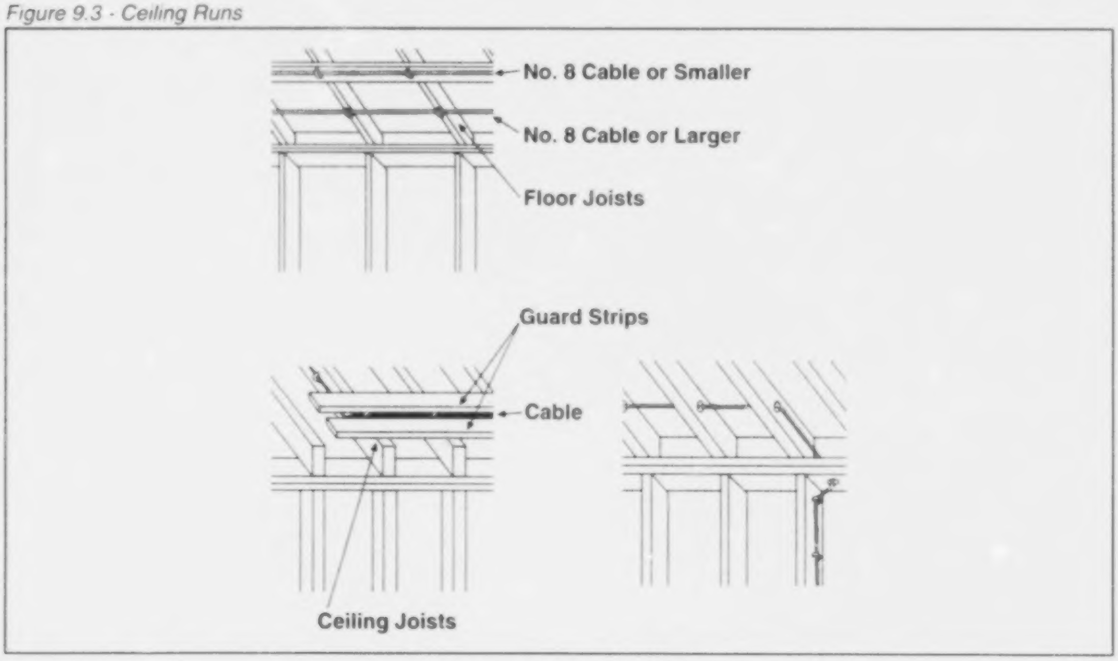
Running the Wires

Once the labeling is complete, wires can be run in the structure. Protecting the wire is an important consideration. Excessive bending of electrical conductors should be avoided to prevent the insulation from cracking, which could cause the wire to short out. Also, wire is run inside of walls and ceilings to prevent physical damage to the wires. Any exposed wire runs or runs where damage may be a concern, such as in walls where moisture damage could occur, should have the conductor placed inside of a conduit.

A few general practices should always be followed when running wire in a structure. Conductors should run as straight as possible from the SEP to the individual outlets. To reduce the possibility of system failure, as few splices as possible should be used. Wire runs should be as high and dry as possible.

Conductors may be run through the floor or ceiling. Ceiling runs are best because damage from traffic is minimized. They also reduce wire damage because the wires are not located where water may collect or flow. Examples of ceiling runs are shown in Figure 9.3. If runs must be under flooring, noncorrosive conduits should enclose the wires.

Figure 9.3 - Ceiling Runs



Placing electrical runs in the walls is also common. Four approved methods are used to place electrical conductors within a wall; they are illustrated in Figure 9.4. The first method requires the drilling of a hole in the center of the wall studs. The hole should be large enough to accept the conduit or to allow the cable to slide through easily without friction and binding. Wire can also be stapled along the side of a stud. A third method of running wire involves cutting a notch in the side of the wall studs. A steel cover plate is installed over the notch after the wire is in place. In structures where moisture will not be a factor, wire can be run in the walls by notching the bottom of the studs and running the wires along the bottom plate of the wall. This last alternative lessens problems with installing insulation later.

Tools for Wiring a Receptacle or Light

Gathering all the necessary tools is an important first step before installing anything. As with any construction task, the use of the proper tools is essential to working safely and efficiently.

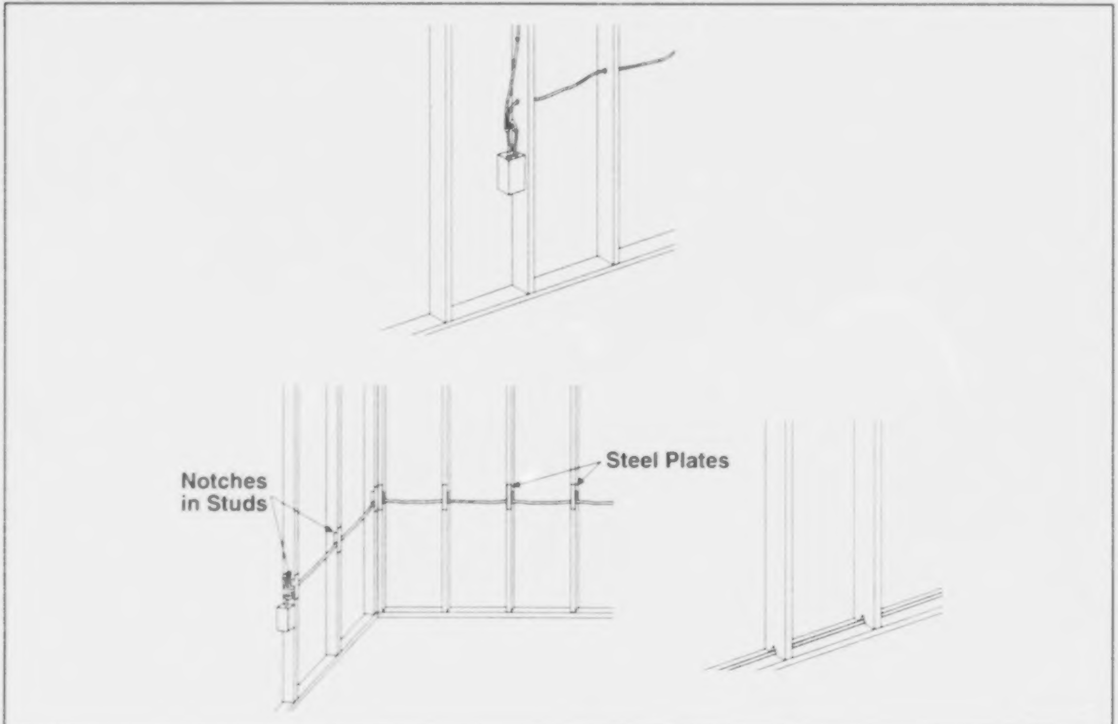
Numerous tools can be used in electrical wiring. However, a few essential tools must be on hand to do a good job with installations.

- Wire cutters, either lineman's pliers, side cutting pliers, or needlenose pliers
- Cable rippers, which is used to remove the cable covering from the conductors housed in the cable sheathing
- Wire strippers for removing insulation from conductors
- A complete set of screw drivers
- Hammer
- Slip-joint pliers
- Level
- Tubing cutter for cutting conduit
- Conduit bender, which is used to bend or form conduit to turn corners

Other tools can also be used to accomplish wiring tasks more efficiently. They include the following:

- Socket wrenches
- Drill motor and drill bits
- Adjustable open-end wrench
- Hand saw
- Electrical testing equipment

Figure 9.4 - Wall Runs



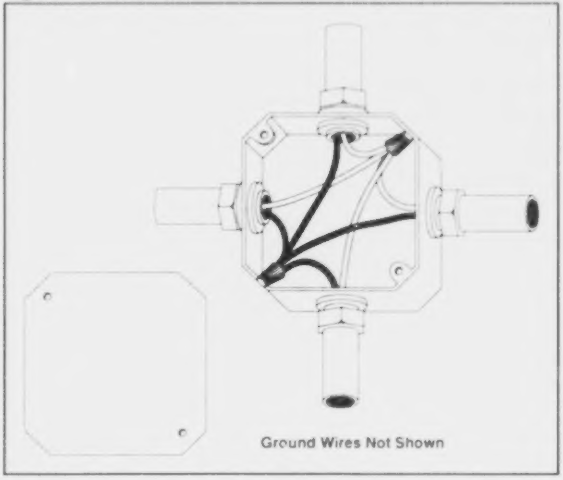
The Function of a Junction Box

When wiring circuits, branching the circuit is sometimes necessary. Branching is splitting the circuit to allow power to run in two or more directions. A junction box is used to protect the wires that are spliced together to branch circuits. Junctions are sometimes needed if a long electrical run is required or if no convenient outlets are available from which to branch power to different outlets on the same circuit.

A junction box is basically an outlet box with a solid cover. The NEC states that all boxes in which splice connections are made must be dust tight and watertight. The NEC also requires that they be made of corrosion-resistant material. Junction boxes should be located where they are permanently accessible for repairs.

Connections in a junction box should be made carefully, paying attention to detail. The ends of the wires are inserted into the junction box through the knockouts, which are specially designed parts of the junction box that can be removed. About 6 inches of each wire should pass through the knockouts. When splicing conductors together, black wires are connected to black wires, white wires to white wires, and ground wires to ground wires. If the outlet box is metal, a separate piece of wire should be connected to the box and the ground wires. The wires should be clamped securely to the box to prevent the splices from pulling apart. A junction box is shown in Figure 9.5.

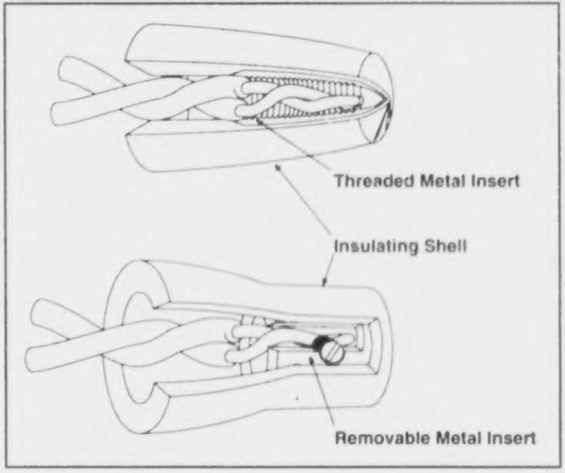
Figure 9.5 - Junction Box



Techniques for Splicing Wires

For most electrical wiring, solderless connectors are used to splice wires. Several different types of solderless connectors are used, including threaded metal insert connectors, removable metal insert connectors, and spring-loaded connectors. These connectors are pictured in Figure 9.6. They all perform the same basic function of efficiently joining two or more wires.

Figure 9.6 - Solderless Connectors



Insulated solderless connectors, commonly referred to as wire nuts, are easy to use. To splice wires, the wire insulation is stripped back just enough for the wires to fit inside the connector. The wires are then laid together. The method for connecting the wires depends on the connector selected. With the threaded metal insert connector, where the insert is contained in an insulating shell, the connector is screwed onto the wires to be joined. For the removable metal insert connector, the insert can be removed from the insulating shell. The insert slips over the wires, and the set screw in the insert is tightened to lock the wires in place. The insulating shell then screws back on over the insert. The spring-loaded connector is similar to the threaded metal insert in that it screws onto the wires to be spliced. Inside of the insulating shell is a cone-shaped spring that holds the wires together when screwed onto the wires.

When using solderless connectors, taping the conductors may be necessary. If the correct amount of insulation has been removed, tape is not needed because the insulating shell of the connector will protect the bare wires. However, if bare wires are exposed, electrician's tape is wrapped around the connection to protect the wires.

When splicing wires that are AWG 8 and larger, different connectors are needed. For these situations, metal connectors are used. They have a collar with a set screw. To splice wires, the wires are inserted into the connector, and the screw is tightened to hold them in place. The connector and wires are wrapped with electrician's tape to protect the joint.

Wiring a Light Circuit

Almost every structure that has electrical power will have some form of lighting. Understanding the principles behind the proper wiring of lights and switches is necessary to efficiently and correctly connect these circuits.

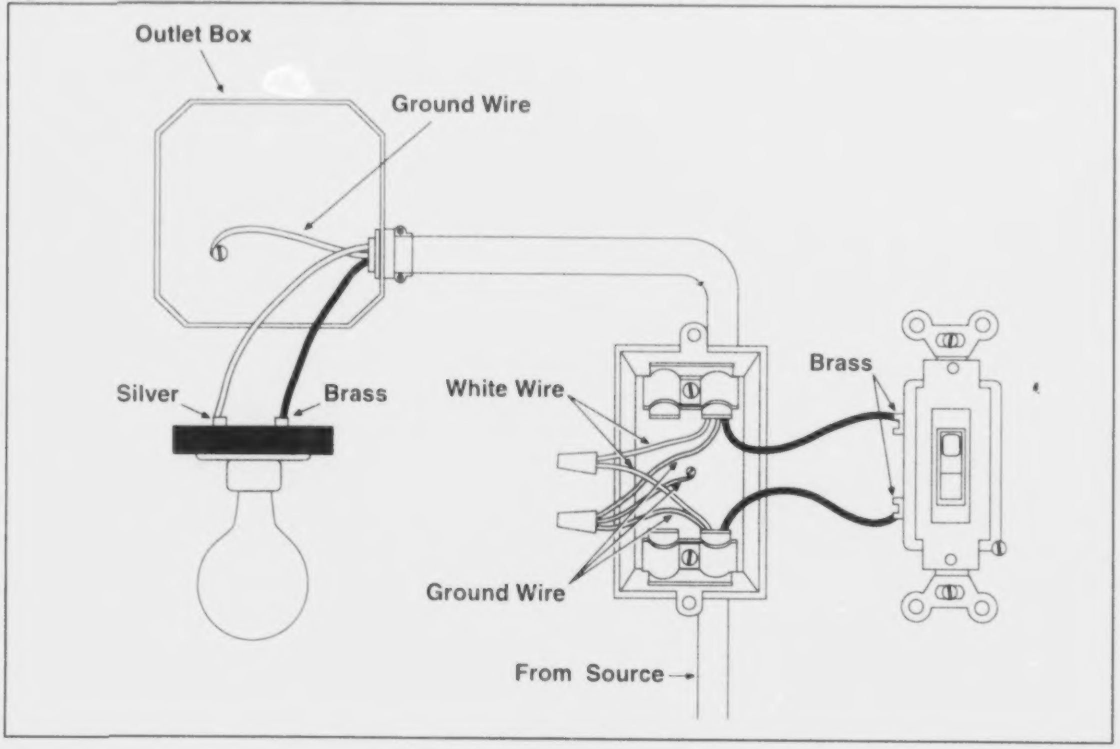
Before wiring any type of light circuit, the wires must be inserted into an outlet box. Six inches of the insulation is removed before inserting the individual wires into the box. Box connectors, or special connectors that attach to the electrical box and clamp the conduit in place, hold the wires in place as they enter the box.

The most basic light circuit is the simple circuit. For this circuit, the black hot wire connects to a brass screw on the light fixture. The white neutral wire connects to a silver screw. The electrical flow through the fixture and the attached lamp provides light. This system is impractical because the light cannot be turned on and off.

A switched circuit allows a light to be turned off. In a switched circuit, a switch breaks the electrical circuit of the light fixture. When the switch is open, it interrupts the flow of electricity and turns the light off. When the switch is closed, electricity flows through the circuit, creating light.

Wiring a switched circuit, as shown in Figure 9.7, is relatively simple. White, black, and ground wires enter the switch box from the power source. The white source wire is connected to a white wire with a connector. The black source wire is connected to a brass screw on the switch. Another black wire is attached to the other screw on the switch. At the light fixture, this black wire is

Figure 9.7 - Switched Circuit and Light



connected to a brass screw and the white wire to a silver screw. A green ground wire from the light fixture is connected to the ground wire from the source using a solderless connector. If the boxes are metallic, the ground wires are attached to the boxes with a piece of wire.

In a switched circuit, the power may be brought from the source to the light fixture box rather than to the switch. A switch loop is used to carry the electricity to the switch. In a switch loop, a pair of black wires brings the power to the switch from the lighting box and carries it back to the light, as illustrated in Figure 9.8. The black source wire is connected to a length of black wire with a connector. This wire is connected to a brass screw on the switch. Another black wire is connected to the other brass screw on the switch. This second black wire runs back to the lighting box. It is attached using a connector to a black wire from the brass screw on the fixture. The white source wire is connected to a white wire from the light fixture using a connector. The white wire is attached to a silver screw at the light fixture.

A three-way switch controls another type of lighting circuit. Using a three-way switch, a light can be turned off and on from two different locations. The wiring requires the use of a three-wire cable with black, white, and red conductors plus a ground wire.

Wiring a three-way switch begins at one of the switches. The black wire from the power source is connected to the common terminal on the switch, which is the side of the switch with one terminal screw. A black wire is connected to the switch on the opposite side from the black source wire. A red wire is connected to the other terminal on that side. The white wire from the source is spliced to another white wire with a solderless connector. Appropriate ground connections are made at the switch.

Next, the other wires are connected at the second switch. A black wire is connected to the common terminal of the switch. A red wire is attached to the terminal opposite the black wire, and a white wire is connected to the other terminal. The ground connections are then made in the box.

The wires from the two switches meet at the light fixture. The black wire from the first switch is connected to the white wire from the second switch using a solderless connector. A connector is also used to splice the red wires together. The black wire from the second switch is attached to the brass screw on the fixture, and the spliced

Figure 9.8 - Switch Loop

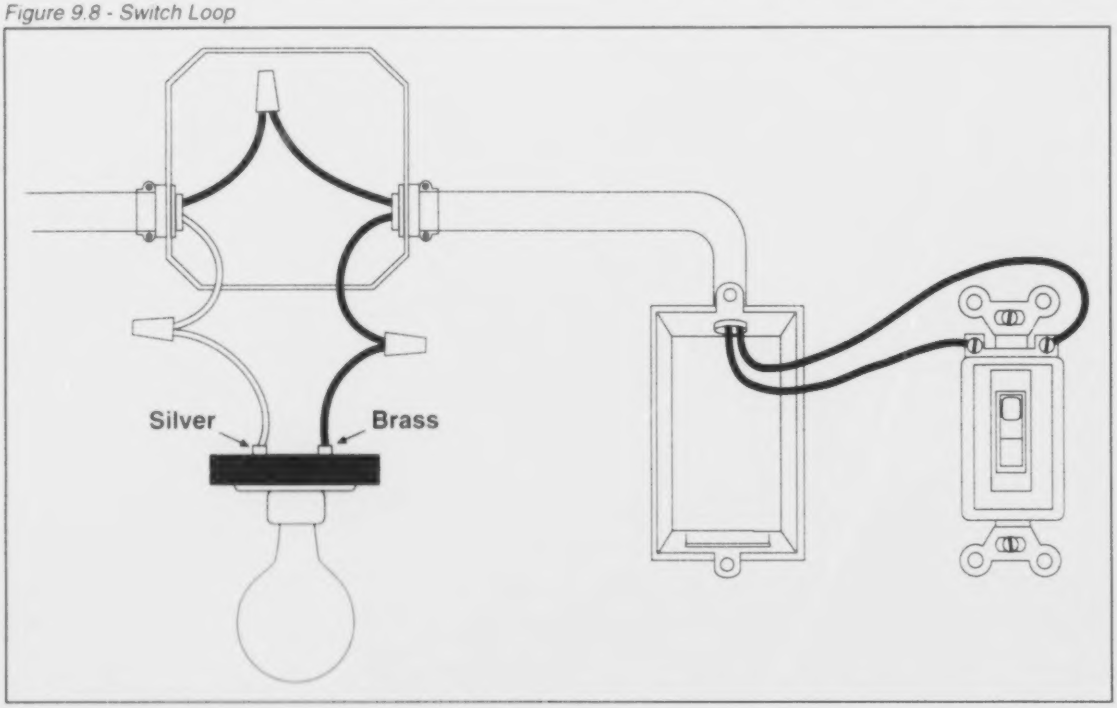
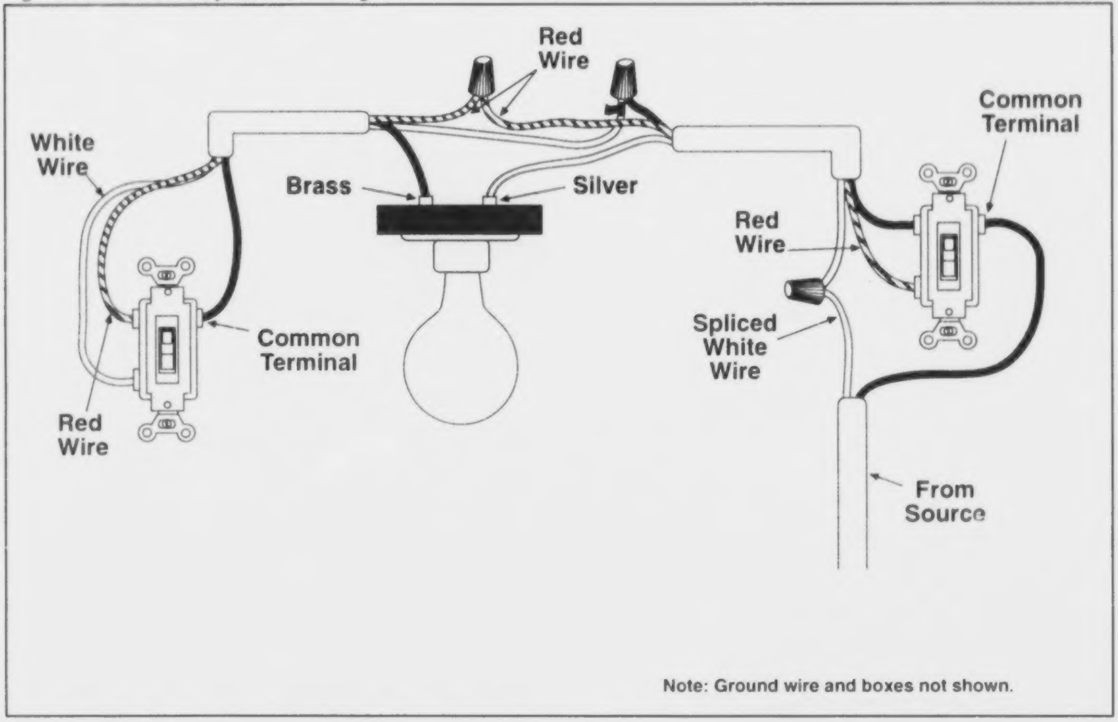


Figure 9.9 - Three-Way Switch and Light


Red
Wire
White
Wire
Common
Terminal
Brass
Silver
Red
Wire
Common
Terminal
Spliced
White
Wire
Red
Wire
From
Source
Note: Ground wire and boxes not shown.

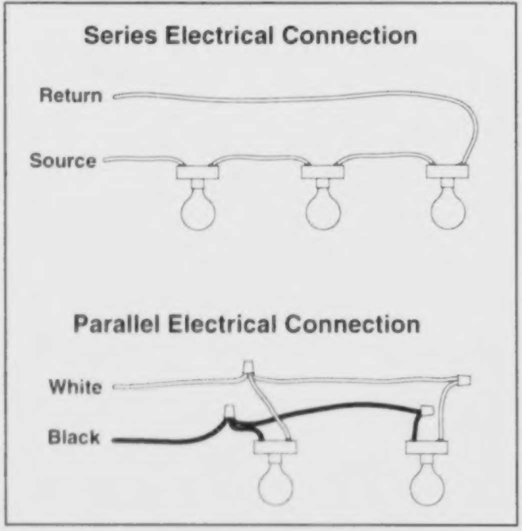
white wire from the power source is connected to the silver screw. A completed three-way switch is pictured in Figure 9.9.

Series and parallel wiring are two methods used for wiring two or more light receptacles together. These methods are used when more than one light fixture is on a circuit. They are illustrated in Figure 9.10.

Series wiring is an impractical system except for special purposes because the way the outlets are connected, if one light goes out, they all go out. Series wiring is primarily used in situations where a burned out light needs to be addressed immediately. To install a series system, the black wire from the source is attached to a terminal on the first fixture. A white wire then runs directly from the second terminal to the next lighting fixture and attaches to a terminal there. Another black wire runs from the second terminal on that fixture directly to the next fixture. This pattern continues through the series. If one lamp burns out, it breaks the circuit, thus cutting off electricity to all the lights on the circuit.

Parallel wiring is the most common method of wiring multiple light fixtures. In parallel wiring, jumper wires attached to each light fixture are spliced to the white and black wires from the

Figure 9.10 - Series and Parallel Wiring


Series Electrical Connection
Return
Source
Parallel Electrical Connection
White
Black

power source. This system allows power to flow separately to each individual lamp on the same circuit. If one lamp burns out, the other lamps will still receive power for lighting.

Wiring Convenience Outlets

Convenience outlets provide electrical connections for tools and equipment. Therefore, wiring them properly in the electrical circuit is necessary. Outlet receptacle devices are easy to install and can be connected in a series. These receptacles can be controlled with switches.

Wiring a receptacle circuit begins with attaching the black source wire to the side of the receptacle with the brass screw. The white wire is attached to the silver screw on the opposite side of the receptacle. The ground wires are joined using a connector. A wired receptacle is illustrated in Figure 9.11.

The procedure for wiring two or more receptacles on a circuit is more complicated. The first receptacle is connected as described. Another black wire is then connected to the other brass screw on the first outlet and to the brass screw on the second receptacle. A white wire is connected to the second silver screw on the first receptacle and the silver screw on the second. The same procedure is followed for any other receptacles on the same circuit. The appropriate ground connections should then be made.

Summary

Planning the location of circuits and equipment to be installed is useful. Not only does a wiring diagram identify how electrical runs will be laid out but also where electrical outlets will be installed. Once the plan is finalized, the proper tools to do the job should be gathered together. Lights and receptacle outlets can be then be installed using the proper techniques.

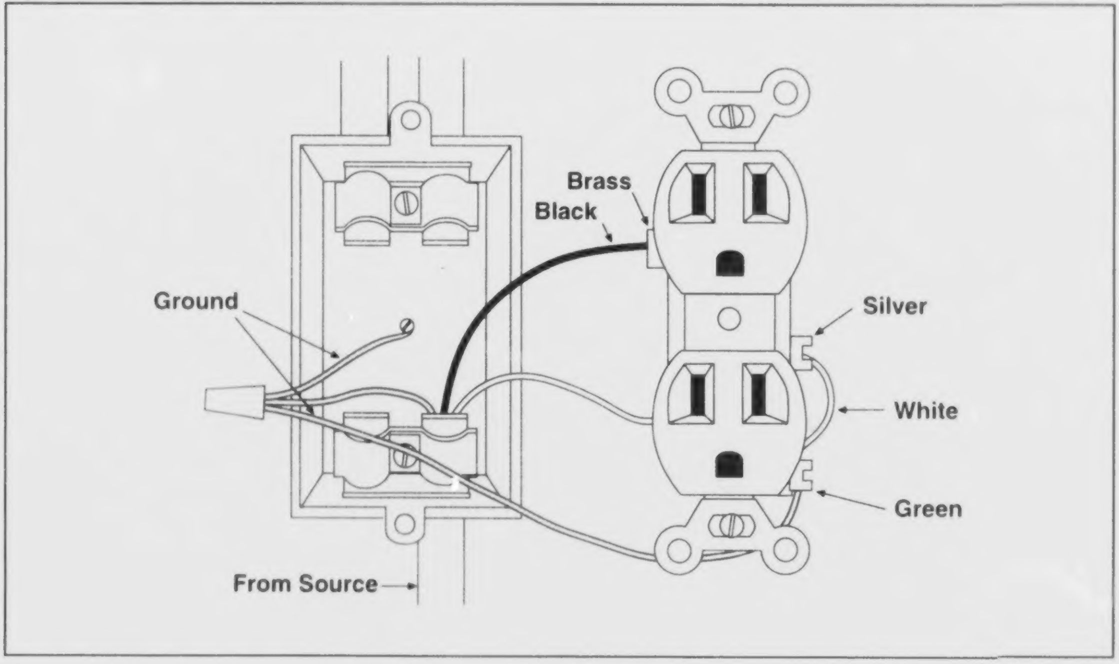
Credits

Holzman, H.N. *Modern Residential Wiring.* South Holland, Ill.: Goodheart-Willcox Company, Inc., 1986.

Mix, Floyd M. *House Wiring Simplified.* Tinley Park, Ill.: Goodheart-Willcox Company, Inc., 1996.

Richter, H.P., and W. C. Schwann. *Wiring Simplified.* 38th ed. Somerset, Wis.: Park Publishing, Inc., 1996.

Figure 9.11 - Wiring a Convenience Outlet



Lesson 10: Cost and Electrical Power Use

Once the electrical system is in place, electrical consumption and the cost of electrical use becomes important. Four factors affect calculations related to electric power: watts, volts, amperes, and resistance. The relationship between these factors was first described in 1826 by a German physicist named Georg Ohm, who devised Ohm's Law for calculating electrical resistance.

The Power Equation and Ohm's Law

The power equation is a mathematical formula that expresses the amount of power used in an electrical circuit or system. It indicates the relationship between wattage (P), amperage (I), and voltage (E).

$$P = I \times E$$

This equation is primarily used to calculate power usage in watts, but the formula can also be used to determine the amperage or voltage of a system if the other two factors are known. These calculations are important when testing an electrical system for efficient operation and for calculating the power use of individual branch circuits or the total system.

Ohm's Law is a mathematical formula that expresses the relationship between electromotive force (E), electric current (I), and resistance (R). Electromotive force, which is measured in volts, is the pressure created by the movement of electrons from one point to another. Electric current is measured in amps. The final factor, which is referred to as resistance in DC circuits, is measured in ohms. The formula for Ohm's Law is as follows.

$$E = I \times R$$

When working with AC circuits, impedance (Z) is used rather than resistance. Impedance describes the counter electromotive force created by the directional change in the AC circuit. The strength of the resistance depends on the rapidity of the directional change. The more frequently the electrical current switches directional flow, the higher the impedance will be.

Ohm's Law is used to determine the energy efficiency of an electrical circuit, looking at factors such as voltage drop. It helps electricians determine if changes need to be made in a system, such as using fewer outlets or larger wire sizes. The equation can also help in determining if expanding an existing system is feasible.

To make calculations using the power equation or Ohm's Law, measurements of the electrical system must be made. Handheld electrical meters are available to measure each of the factors used in the equations. An ammeter measures amperage, while a volt meter measures voltage. A watt meter measures wattage, showing how much power is flowing through the system by analyzing both amperage and voltage. An ohmmeter measures resistance in the electrical system. These types of meters are used by electricians to test an electrical system.

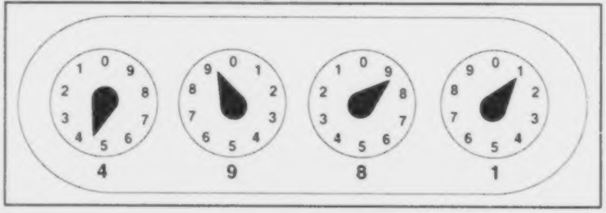
Measuring Electricity

To calculate how much electricity is used, being able to read and understand the measurements used to check electrical consumption is necessary. Electrical power is measured by power companies using a watt-hour meter, which measures and instantly records electrical consumption in watts or kilowatts. The watt-hour meter is attached to the electrical system at the meter base, a socket that the meter plugs into. Meters are located at or near the service entrance panel in homes and on individual structures or at the power pole when a number of structures will be operating on the electrical service.

Two types of meters are commonly used. The newer type uses a rotating meter similar to the mileage indicator on a car. This meter is easier to read than the older type, which has several rotating pointers that turn as electricity is used, as shown in Figure 10.1. The following system is used when reading the pointer-type meter.

- The first dial is read counterclockwise.
- The second dial is read clockwise.
- The third dial is read counterclockwise.
- The fourth dial is read clockwise.

Figure 10.1 - Meter Reading



The numbers are written down from left to right. If the pointer is between numbers, the smaller number is read. The numbers give the kilowatt-hour usage for that point in time.

Determining the Cost of Electricity

Electrical bills are calculated on a monthly or bimonthly basis in most areas. The bills are based on a scale set up by the local electric company. Some companies use a sliding scale that decreases price as usage increases. Others use a fixed rate.

Calculating the cost of electricity requires the rate scale from the electric company and the total kilowatt-hours consumed. To determine the total use over a period of time, the previous meter reading is subtracted from the current one. Cost calculations will vary depending on whether a sliding scale or fixed rate is used, but the basic calculation involves multiplying the rates charged by the amount of electricity used.

For example, suppose that last month's meter reading was 2,000 kilowatt-hours. This month's is 3,511 kilowatt-hours. Using the sliding rate scale given below, what would the cost be?

Sliding rate scale:

$ .08 for the first 100 kWh
$ .07 for the next 200 kWh
$ .06 for the next 300 kWh
$ .05 for the next 500 kWh
$ .04 for over 1,100 kWh

Total kilowatt-hours consumed:

3511 kWh - 2000 kWh = 1,511 kWh

Cost:

First 100 kWh × $ .08 = $8.00
Next 200 kWh × $ .07 = $14.00
Next 300 kWh × $ .06 = $18.00
Next 500 kWh × $ .05 = $25.00

1,511 kWh - 1,100 kWh = 411 kWh
411 kWh × $.04 = $16.44

Total cost:

$8.00 + $14.00 + $18.00 + $25.00 + $16.44 = $81.44

Summary

The power equation and Ohm's Law measure the flow of electricity through an electrical system. They make it possible to calculate loads for each structure, check electrical costs, and plan for future expansion to meet electrical needs. When the electrical system is in use, the amount of electricity used can be calculated by reading the watt-hour meter. This information can be used to determine the cost of electricity.

Credits

Holzman, H.N. *Modern Residential Wiring.* South Holland, Ill.: Goodheart-Willcox Company, Inc., 1986.

Richter, H.P., and W. C. Schwann. *Wiring Simplified.* 38th ed. Somerset, Wis.: Park Publishing, Inc., 1996.

Lesson 11: Lightning Protection

Lightning strikes the earth 100 times per second every day. In the United States, more than 125 people are killed by lightning each year, not including fatalities from fires related to lightning. Lightning damage also affects electrical systems. In areas where lightning occurs frequently, a properly installed lightning protection system is necessary.

Why Lightning Strikes

Lightning is the visible discharge of static electricity. This discharge can occur within a cloud, between clouds, or between the earth and a cloud. Basically, lightning is a large electric spark caused when current jumps a gap in the air.

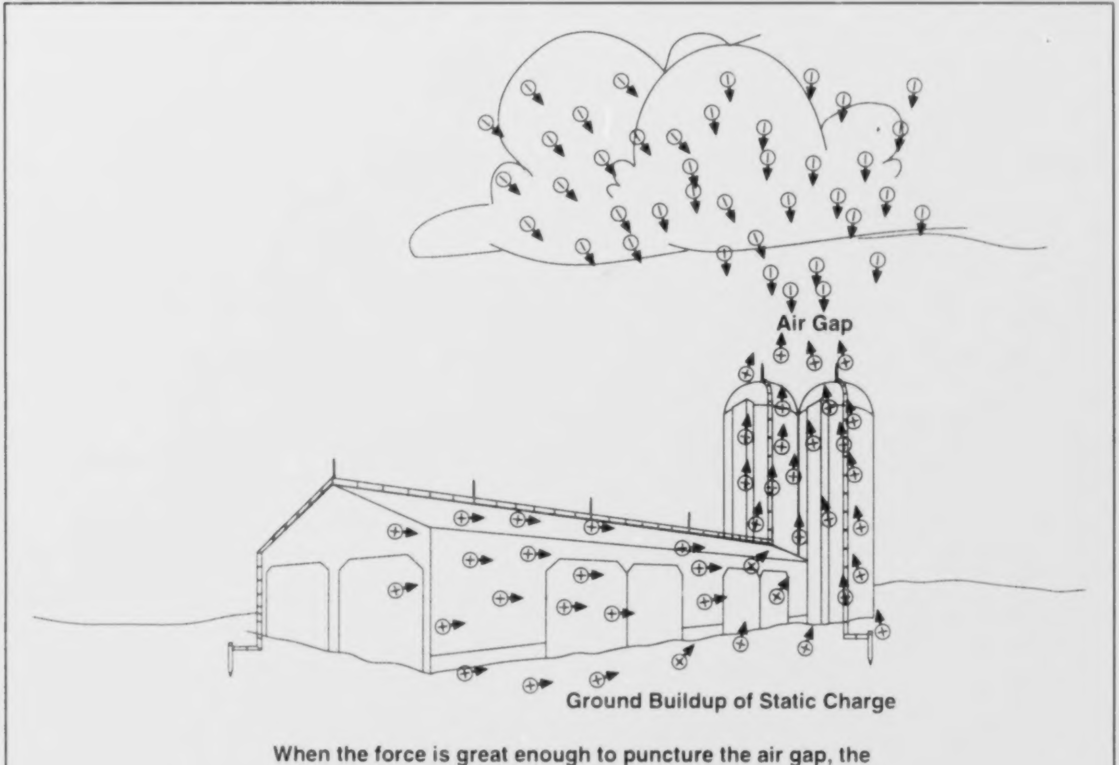
Strikes occur when hot and cold air masses meet, causing atoms to lose electrons. Once freed, negatively charged electrons gather at the cloud base. Positive ions converge at high locations on the earth's surface, such as hilltops, silos, buildings, and trees, as illustrated in Figure 11.1. The ions and electrons are attracted to each other, creating a stepped leader, which is an unseen conduit through which negative charges move from the cloud to the earth. From the earth, ion streamers called leaders travel upward. If the two puncture the air gap insulator and converge, a channel is created for electrical energy to move between the earth and the cloud as the charges rapidly equalize themselves.

The average lightning bolt lasts from 1/1000 to 1/10 of a second and can produce temperatures up to 50,000 degrees Fahrenheit. It can create 1 million volts of electricity. Therefore, lightning protection is necessary for protection from fires and electrical surges.

The Need for Lightning Protection

A lightning protection system provides a path for lightning to the ground that is an alternative to traveling through a building or equipment. It

Figure 11.1 - Conditions for Lightning Strikes



When the force is great enough to puncture the air gap, the charge follows the path of least resistance to the ground.

prevents damage to structures and keeps people and livestock from being injured. It does not directly attract lightning or prevent a lightning strike. Proper planning is essential in developing a lightning protection system that will efficiently protect people and property.

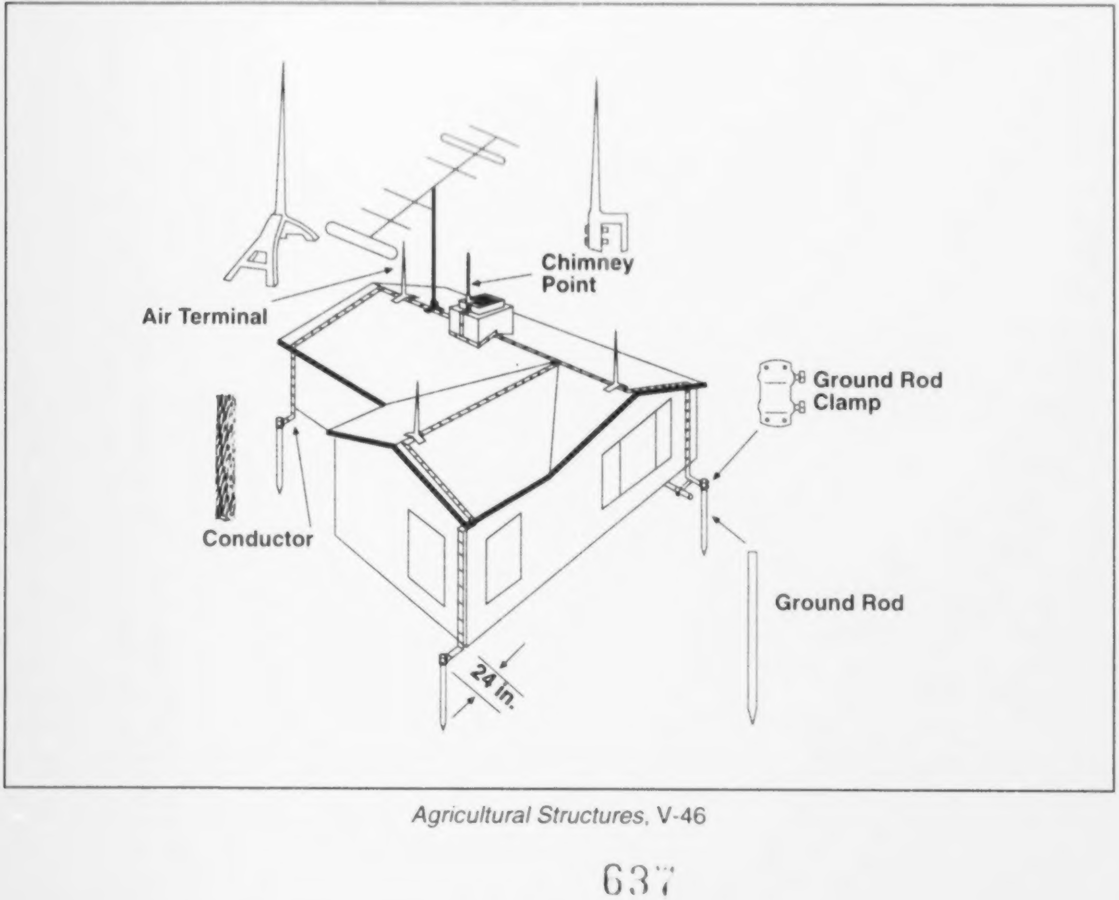
Before installing lightning protection, the need for such protection should be assessed. The National Fire Protection Association has published a risk assessment guide in their Lightning Protection Code, while insurance companies may also provide assistance in assessing the risk of damage from lightning. Factors considered include the frequency of lightning, the type of structure and its construction, the location of the structure, the topography of the surrounding area, and the contents of the structure.

In addition to these factors, a few other considerations exist for agricultural operations. Tall structures such as silos should be grounded not only to protect them but because they can provide a cone of protection with a diameter that is two times the height of the object. This cone can protect other structures that fall within it. Also, like buildings, electric fences should be grounded.

A Good System of Protection

A good lightning protection system has some basic components shown in Figure 11.2. Air terminals, or lightning rods, are the points where lightning strikes. Air terminals need to be installed on high points on structures, such as roof ridges or ventilators. The main conductors are the cables that connect the air terminals to the grounding electrodes, or ground terminations. The ground terminations are copper or copper-clad rods driven into the earth, preferably to a minimum of ten feet in depth. Lightning arresters are used to protect electrical wiring from lightning-induced damage. They are installed at the service entrance. Surge suppressors are used to further protect electrical equipment, such as computers. They are typically small boxes into which electrical equipment is plugged. Arresters and suppressors work by breaking the electrical circuit when an overload is present. These devices handle any residual current that may leak through the main lightning protection system.

Figure 11.2 - Components of a Lightning Protection System



Installing the Lightning Protection System

Proper installation is crucial to an efficient lightning protection system. Most insurance companies follow the guidelines described when they inspect the system to see if it is acceptable. A qualified professional should install the lightning protection system to make sure the proper procedures are followed.

Some general design rules apply to all lightning protection systems. These rules affect the number of grounding electrodes and the grounding cables. All buildings with a perimeter of 250 feet or less must have two grounding electrodes, preferably diagonally at opposite corners of the structure. If the perimeter is between 250 and 350 feet, three electrodes are required. At perimeters of 350 to 450 feet, four electrodes are necessary. As the perimeter increases, another grounding electrode is added for every 100 feet of perimeter. Also, the grounding conductors should follow a straight horizontal or vertical path to the grounding electrode. The cables need to be free of sharp turns and "U" or "V" pockets, which are sharp kinks or small bends in the cable. Turns in conductors should not exceed 90 degrees, and bends should not have a radius of less than eight inches. Sharper bends can restrict the flow of electricity.

Certain guidelines must be met when installing a lightning protection system. For proper protection, air terminals should be properly sized, spaced, and installed to receive lightning strikes. The down conductors, which are the vertical conductors that are attached to the ground rods, should carry the discharge directly to the ground. Entrance conduits, gutters, drain pipes, pipe vents, metal water pipes, radio and T.V. antennas, metal roofing, fences, and other metal objects should be bonded or connected to the down conductors and ground rods. The main bonding conductors must be at least AWG 6 copper wire or its equivalent. Down conductors should be enclosed in a conduit or metal tubing. The conduit should extend from a point at least five feet above ground level to one foot below the ground's surface to provide protection against physical damage.

Ground rods of adequate size must be located properly throughout the system. Lightning system ground rods must be driven to a minimum depth of 10 feet where soil conditions permit. If grounding electrodes cannot be driven to this depth, other acceptable options are to dig a trench 3 to 4 feet deep by 10 feet long and bury a grounding rod or to bury a grounding plate at least 18 inches deep. Another method of grounding involves connecting down conductors to a metallic water system, as long as the pipes are a minimum of three feet deep and ten feet long and are in direct contact with the earth. If ground rods used for the electrical or telephone system are within 6 feet of a grounding electrode for the lightning protection system, they must be bonded together to prevent side flashes, or the arcing of electricity between conductors. Side flashes can lead to fires, physical damage, and power surges to other electrical systems.

Protecting Equipment from Lightning

Protecting equipment is another important reason to install lightning protection. Overloads can cause tremendous damage to electrical systems and equipment. The power supply system has built-in lightning protection. A number of devices are also used to protect individual pieces of equipment from lightning.

The power supply system itself serves as protection from lightning. As power comes from the source, it passes through several transformers and other devices that reduce and convert the electricity into forms the consumer can use. This process is referred to as "stepping down." Lightning protection is offered at each level.

Surge suppressors, as discussed previously, are used to protect electronic equipment, particularly computers, from surges or spikes of electrical current. These devices provide a receptacle or a bank of receptacles with a breaker that automatically trips when the electricity spikes. If computer equipment is plugged into telephone lines, the lines also require surge suppressors to prevent damage from lightning. Telephone companies place lightning suppression devices in the lines. Special surge suppressors have connections for telephone lines.

Lightning or surge arresters are used to remove high voltage charges from the system by breaking the circuit and then diverting the electricity to the ground. These devices act as a safety valve, draining power surges out of the system. They are installed where service wires enter the building at the service entrance panel or prior to the connection of specialized electrical loads, such as submersible water pumps or feed handling equipment, or other equipment away from protected buildings.

Controllers are another type of device that helps protect electrical equipment from lightning. All motors must have some type of controller, which is normally used for starting and stopping the motors. For small motors of ⅛ hp or less, the overcurrent device at the service entrance panel is sufficient to act as a controller. However, for larger motors, a separate switch with a current capacity at least twice the full load rating of the motor is required. The controller should have overload devices installed that stop the current to the motor during electrical surges and power overloads. These devices should also have a manual reset so the motor does not restart automatically when normal power is restored.

Grounding Lightning off a Structure

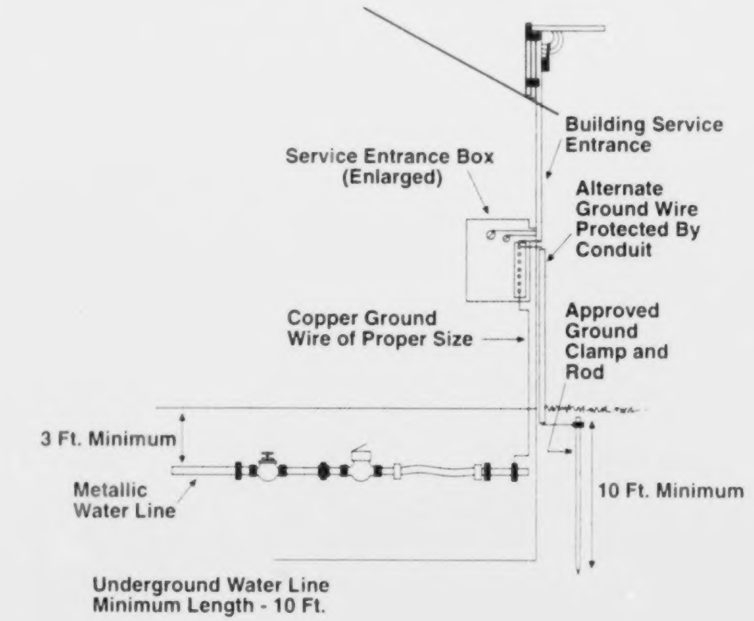
The grounding of the lightning protection system will determine the extent of protection available. Grounding consists of connecting one end of a properly sized copper conductor to the air terminals and the other end to a metal conductor that is in direct and permanent contact with the earth, as shown in Figure 11.3. A ½-inch copper rod, a ⅝-inch copper-clad rod, a ¾-inch galvanized iron pipe, or a metallic water system should be used for grounding. If a ground rod cannot be used due to rock beneath the soil, a metal plate may also be buried underground to serve as a ground. The size of the grounding wire is determined by the size of the wire supplying power to the service entrance panel, as indicated in Table 11.1.

Table 11.1 - Wire Sizes

Service Entrance Wire Size	Copper Ground Wire Size
Up to AWG 2	AWG 8
AWG 1 or 0	AWG 6
AWG 00 or 000	AWG 4
AWG 0000 or larger	AWG 2

When installing the grounding system, the wire is clamped to the grounding electrode using lugs or clamps. A steel strap or solder should not be used to attach wires because these methods are

Figure 11.3 - Grounding Practices


Building Service Entrance
Service Entrance Box (Enlarged)
Alternate Ground Wire Protected By Conduit
Copper Ground Wire of Proper Size
Approved Ground Clamp and Rod
3 Ft. Minimum
Metallic Water Line
10 Ft. Minimum
Underground Water Line Minimum Length - 10 Ft.

structurally weak and may not provide the contact needed during a lightning strike.

Summary

An efficient lightning protection system is necessary to help prevent damage to buildings and equipment and loss of life. The system should consist of properly sized and placed air terminals, down conductors, bonding conductors, and grounding electrodes. It should also include protection for equipment, such as surge suppressors, arresters, and controllers. It is highly recommended that a qualified and certified professional install this system for the home and farm.

Credits

Electricians Toolbox Etc. "Lightning Protection." http://www.elec-toolbox.com/usefulinfo/lightprot.htm (8 Feb. 1999).

Holzman, H.N. *Modern Residential Wiring.* South Holland, Ill.: Goodheart-Willcox Company, Inc., 1986.

Lightning Protection for Missouri Farms and Homes (G1020). University Extension agricultural publications, 1993.

Richter, H.P., and W.C. Schwann. *Wiring Simplified.* 38th ed. Somerset, Wis.: Park Publishing, Inc., 1996.

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Lesson 12: Detecting Problems

After installation, problems may arise in the electrical system. These problems can be the result of improper wiring, misuse, or just wear on equipment. When problems occur, detecting what the problem is and correcting it is important. Investigating the nature of the problem may require the use of different testing devices.

Testers Used in Troubleshooting

A variety of meters and testers can test electrical systems. Three of the more common are the neon tester, the voltage tester, and the VOM meter. Figure 12.1 shows examples of these testing devices.

The neon tester is the simplest device used by electricians. This tester can be used on either a 120-volt or 240-volt system. A glowing light indicates that voltage is present in a circuit. The greater the voltage in the circuit, the brighter the light glows.

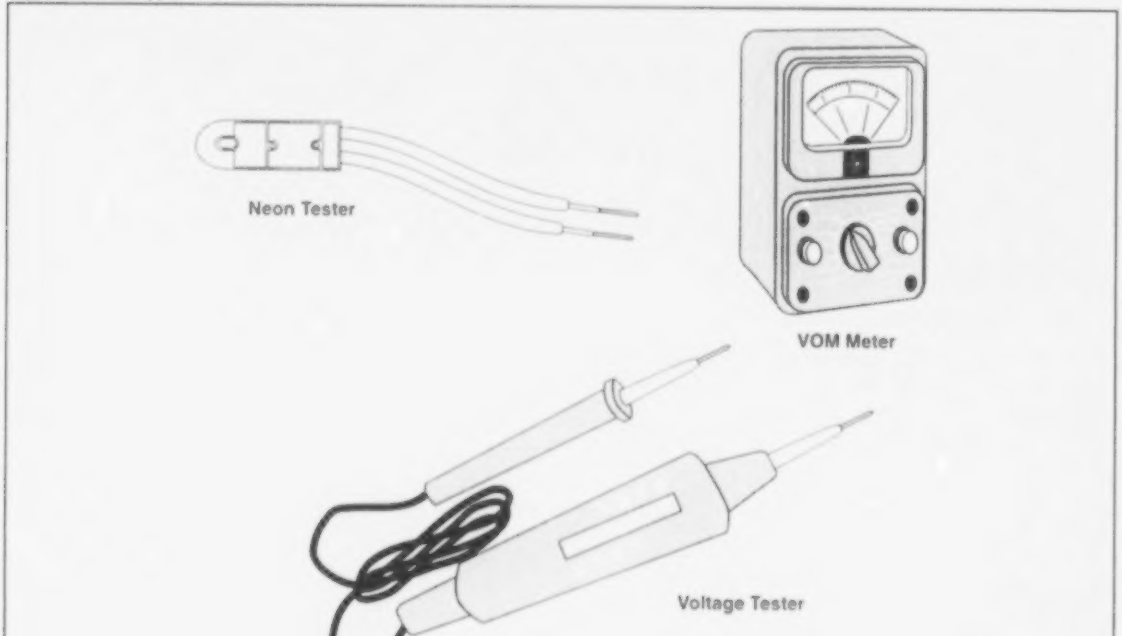
A voltage tester is used to indicate the voltage and polarity, or direction of electrical flow, in a circuit. The tester uses a series of neon lights to indicate the approximate voltage moving through the circuit.

Another type of tester is a VOM meter. VOM stands for volt-ohm-milliammeter. This tester supplies the same information as the others, displaying the voltage and polarity of the circuit. It also provides accurate measurements of circuit resistance and amperage. To provide this information, this testing device combines a voltmeter, ohmmeter, and ammeter in one casing. The voltmeter measures the voltage across two points in an electrical circuit. The ohmmeter measures resistance, and the ammeter measures the electrical flow or amperage. The VOM meter provides this information on a calibrated numerical scale.

Using Testing Devices

To safely determine what type of electrical problem exists, it is important to know how to use testing devices properly. All testers come with manufacturer's directions for their use. These instructions should be read prior to using any type of testing device.

Figure 12.1 - Types of Testers



A neon tester is commonly used for testing outlet receptacles. It has two leads attached to the tester. To use a neon tester to test a receptacle, the ends of the leads are placed into the parallel slot openings. If the tester lights up, no problem exists. If the tester does not light up, the end of one of the leads is inserted into the ground opening, with the other lead in one of the other slots. If the tester lights up, the problem is with the neutral connection or the neutral wire, which is not allowing electricity to flow beyond the receptacle. However, if the tester still does not glow, the outlet cover plate and receptacle are removed. The leads are then touched to the opposite terminal screws. If the tester lights up, the receptacle does not function and should be replaced.

The voltage tester can test outlets, switches, fixtures, and other electrical devices. Like the neon tester, it has two leads attached to the tester housing. It works in a similar way. However, the voltage tester also indicates whether an electrical system carries 120 volts or 240 volts as well as the polarity of the system.

A VOM meter is similar to the other testers in that it has two leads. However, the leads are color coded, with red used for the power side and black for return or neutral side of the circuit during testing. The leads are used as they are with the other testers; for example, to test a switch, the leads are connected to the terminals of the switch after the cover plate is removed. Some special considerations exist when using the ohmmeter portion of the meter. The ohmmeter contains its own power source, so all power to the electrical system should be disconnected before testing for circuit resistance. If the power is not shut off, damage to the meter will occur.

Summary

Three types of testers are commonly used when examining electrical systems for problems. They are neon testers, voltage testers, and VOM meters. To properly troubleshoot the electrical system, it is important to be competent in the use of the various testing devices. Before using any testing device, carefully read all the manufacturer's instructions to avoid problems.

Credits

Holzman, H.N. *Modern Residential Wiring.* South Holland, Ill.: Goodheart-Willcox Company, Inc., 1986.

Richter, H.P., and W.C. Schwann. *Wiring Simplified.* 38th ed. Somerset, Wis.: Park Publishing, Inc., 1996.

Lesson 1: Water Needs

Water is critical to most agricultural operations. Calculating the volume of water needed and determining suitable sources of water is one of the responsibilities of a farm planner. These questions may be difficult to answer precisely. However, suitable estimates are necessary to ensure that an agricultural operation can function effectively.

Sources of Farmstead Water

Water for agricultural operations is generally available from a variety of sources. The most common artificial sources are public water services, wells, and cisterns. Public water supplies generally provide a safe, dependable water supply, but this water source is not available in all areas, making private water sources necessary. Wells can provide a large quantity of safe water with relatively little maintenance. Underground wells may be either shallow or deep. Shallow wells will give sufficient water, but the quality of water will be poorer, because the water is not filtered through as much soil for purification. Deep wells will have cleaner water and usually contain a larger volume of water, although they are more expensive to drill. Cisterns can store rainwater for domestic use but may not supply enough for livestock.

Ponds may be natural or man made. They often supply livestock with water and, with the proper construction and purification, can be used for humans as well. Protection from pollution can be a problem.

Natural sources of water, such as creeks, streams, and springs, are also useful to farm operations. However, they may not be able to provide enough water to meet the needs of the operation. Also, flooding, droughts, and the changing topography of water courses can make these sources of water unreliable for most irrigation and animal needs. Operations that utilize natural sources of water must be flexible enough to operate successfully in a variety of conditions.

The construction involved in developing some water sources, such as wells and ponds, is beyond the scope of the average producer and requires the assistance of knowledgeable professionals. Further information about wells and ponds is available from local University Extension offices.

Selecting the correct water source for an operation involves a number of different factors. The water sources already available, the uses of the water, and the costs of developing new sources should all be considered. Underground wells are the preferred water source for human consumption, but water for animal needs, irrigation, cleaning, and other uses can be from ponds, rivers, reservoirs, and other sources because the quality is not as important. The major exceptions to this rule are dairy operations and large hog operations, where high quality water is preferred. These types of operations require optimal water quality to maximize production.

Water Uses on a Farmstead

The uses of water from these various sources will depend on the type of agricultural production taking place. A few uses of water that are essential to many enterprises are drinking water for livestock, water for irrigating crops, and water for sanitation. Another common use of water is for cooling systems in some types of facilities, such as greenhouses or hog facilities. Water can also be utilized as a delivery system, by adding fertilizer to water while irrigating or medication to the animals' drinking water. If a home is located on the farmstead, water will also be used by humans for various domestic purposes.

Determining Total Daily Water Need

The exact amount of water required for the different uses of agricultural operations would be very difficult to calculate, because conditions that affect water needs, such as temperature and humidity, change regularly. However, the total amount of water normally required to meet the daily needs of an operation can be closely estimated. The first step in making this estimate is finding information on water needs. Charts that show the water needs for different types of animals and crops or special circumstances have been developed to help estimate needs. Table 1.1 shows a sample water needs chart. Sources of information about water needs include local University Extension offices and trade associations, which may be the best resource for more specialized products.

Table 1.1 - Water Needs Table

Use	Water Needs
Adult human	50 to 100 gallons per day
Beef animal	8 to 12 gallons per day
Milk cow	35 to 45 gallons per day
Dry cow	20 to 30 gallons per day
Calf	6 to 10 gallons per day
Swine (finishing)	3 to 5 gallons per day
Sow and litter	8 gallons per day
Horse	12 gallons per day
100 chickens (laying)	9 gallons per day
Lawn and garden	600 gallons to apply 1 inch of water on 1,000 square feet of area
Flushing floors	Minimum of 10 gallons per 100 square feet of floor

Once information on water needs for a particular operation has been collected, the total daily water need of the operation can be determined. The first step is multiplying the recommended amount of water for a particular use by the amount of usage; for example, the amount of water needed for a beef animal is multiplied by the number of animals in the herd to find the total amount of water needed for a beef cattle herd. The different water uses are then added together to find the total daily need of the operation. Overestimating the amount of water needed and planning for that amount is better than not having enough water. Keeping accurate records of the amount of water used and what the uses were over a period of a few years will yield very accurate data for future water use projections.

Some producers may wish to take fire protection into consideration when estimating water needs, in addition to the normal needs of the operation. If water for fire protection is desirable, a minimum of 1,200 gallons (at 10 gallons of water per minute for two hours a day with a pressure of 30 pounds per square inch) is required. Twice this amount, or 2400 gallons (20 gallons per minute at 60 pounds of pressure per square inch for two hours per day), would be even more effective.

Determining Peak Water Need

After estimating the total daily water needs, the peak water needs for a farmstead can be determined. The volume of water a water source can deliver is usually measured in gallons per hour. The total daily needs should be compared with the hourly output, which should be greater than the daily needs of the operation in order to meet peak water needs. Having a water system that can meet the peak need will be sufficient to supply the operation under most circumstances.

Summary

Water is indispensable to production for agricultural operations. The water may come from a variety of sources, including wells, ponds, and springs. It also has a variety of uses, such as drinking water for livestock, water for irrigating crops, and water for sanitation. While determining the exact amount needed to operate may not be possible, accurate estimates of the total daily water needs and peak water needs can be made and used in planning water systems.

Credits

Annis, William H. *Basic Plumbing Skills*. Athens, Ga.: American Association for Vocational Instructional Materials (AAVIM), 1989.

University Extension agricultural publications, University of Missouri-Columbia.

G1800: Sources for Farm and Home Water Supply
G1801: How to Size a Farm and Home Water System

Lesson 2: Plumbing Safety

Given the need for water in agricultural operations, good plumbing systems are a requirement. Although few people think of plumbing as dangerous, some dangers do exist when working with pipes and fittings. Therefore, using the proper tools and methods is important for safety.

Hazards of Plumbing

Plumbing may involve working in open trenches that range in depth from two to ten or more feet deep. If the trench is deep enough, people can suffocate if the sides cave in and bury them. The sides of any deep trench should be carefully observed for signs of instability, such as loose and collapsing areas. These areas should be avoided until they have been excavated to a safe point. Another situation that requires caution is if heavy excavating equipment is close to the sides of a trench, since the equipment can cause the earth to cave in. The equipment should be removed before anyone enters the area.

Plastic pipes require the use of cleaners and cements, or glues, that contain strong chemicals. These substances can be hazardous because they may produce very strong, sometimes toxic, fumes, making good ventilation a necessity. They may also irritate the skin and be flammable.

Fire can be another danger when working with plumbing. In areas where septic or waste lines are present, methane gas may accumulate. This gas is flammable and can explode. Another potential fire hazard occurs when using a propane torch to join copper pipe. The flame can cause a fire if it comes into contact with combustible materials, such as wood, paper, and clothing. Remember, if plumbing is being installed, water for fire protection may not be available.

Disorganized, untidy work sites can cause accidents. Tripping and falling are common causes of injuries. Small sections of pipe left lying around can be particularly hazardous, since they tend to roll when stepped on. Ladders, which are used to place pipes overhead or in walls, can tip over if they are not set on a level, solid surface.

Plumbing Careers

Plumber
Plumbing retailer
Plumbing educator
Plumbing contractor
Plumbing estimator
Plumbing supply dealer
Plumbing inspector
Well driller

Tools for Safe Plumbing Practices

In the past, metal pipes, consisting of cast iron for drains and copper and galvanized steel for supply lines, were the industry standard. Tile was also a common material for drain lines or pipes. These materials may still be found in older structures, but, with the exception of copper lines (required by building codes under various conditions), they are not a popular choice for new construction. Plastic plumbing materials are much easier to work with and do not require the specialized tools that were necessary for working with their metal counterparts. Because of the decline in popularity of metal pipe, few people choose to invest in the tools necessary to work with it. These tools are quite costly and specialized in function, so they are simply not practical.

A few general tools are needed for plumbing practices. A shovel can be used to dig shallow trenches for pipe; for deeper trenches, heavy earthmoving equipment is necessary. Other tools needed when installing pipe are a level, a claw hammer for removing boards, a ladder, a tape measure, and a drill for drilling holes in walls to run pipes.

Working with plastic pipe requires some additional tools. They include a hacksaw for cutting pipe into smaller lengths and an adjustable wrench to hold plastic pipe fittings. Sandpaper, a knife, or a scraping tool is used to smooth the rough edges of pipe that has been cut, and pipe cleaner removes residue from cutting. Pipe glue is used to join pipes.

If copper pipes are necessary, special tools must be used. A propane torch and soldering material join pipes together. A pipe cutter cuts the pipe into lengths, while a pipe bender bends the pipe. A pipe reamer is used to remove sharp edges after cutting the pipe. A flaring tool is used to widen the end of the pipe. Some copper fittings are designed to seal using compression, requiring that one end of the pipe be widened to prevent the

Figure 2.1 - Copper Pipe Cutting Tools

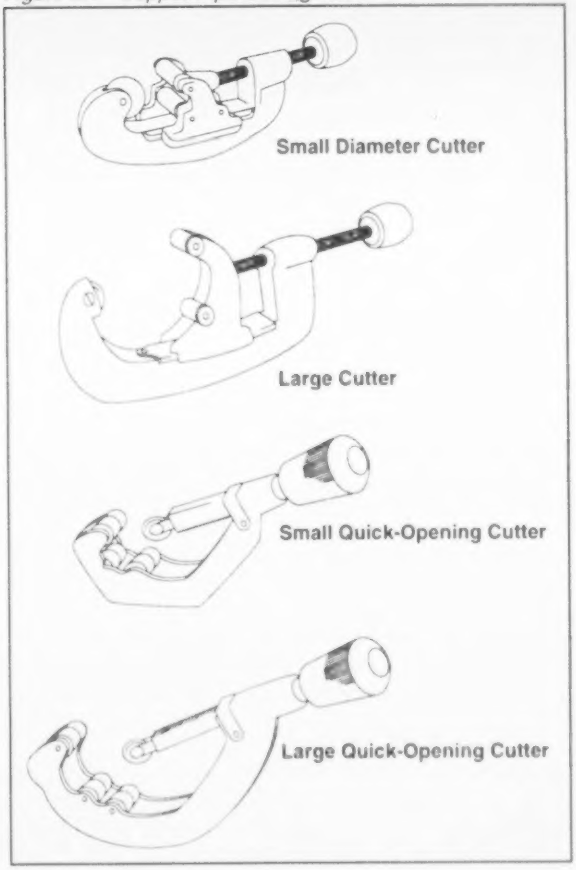
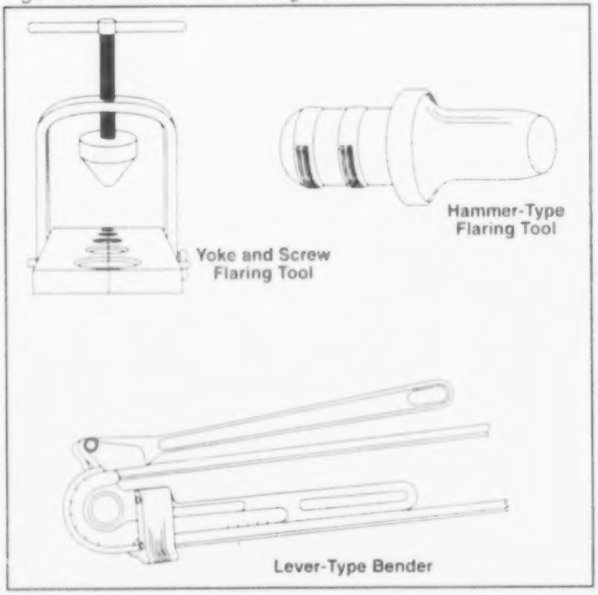


Figure 2.2 - Bender and Flaring Tools



fitting from sliding off. Figure 2.1 shows some different types of pipe cutters. Figure 2.2 shows one kind of bender and different flaring tools.

Using Plumbing Tools Safely

Protective clothing and gear can greatly enhance personal safety while using the plumbing tools listed. A minimum of heavy work pants, boots, gloves, and eye protection is suggested. If injury from above is possible, a safety helmet may be needed.

Most plumbing tools are safe if used carefully. All tools should only be used according to the manufacturer's recommendations. When utilizing plastic pipe cleaners and cements, special attention should be given to any safety recommendations concerning ventilation, skin contact, or fire hazards. If working with plumbing involves soldering copper pipes, using a propane torch will probably be necessary. Extreme caution should be used when working with a torch; proper ventilation and the use of the protective clothing and gear listed above are a must.

Plumbing, like other construction activities, requires that people be alert and cautious to stay safe. Workers must stay focused on the task at hand as well as their surroundings to avoid injuring themselves or others.

Summary

Basic plumbing skills are necessary for constructing many types of agricultural structures. Being aware of any possible hazards is an important part of working with plumbing materials safely. Safety can also be maintained by becoming familiar with the tools needed and how to use them properly. By following these guidelines, the chances of an injury or accident occurring can be greatly reduced.

Credits

Annis, William H. *Basic Plumbing Skills.* Athens, Ga.: American Association for Vocational Instructional Materials (AAVIM), 1989.

Huth, Mark W. *Construction Technology.* 2nd ed. Albany, N.Y.: Delmar Publishers, 1989.

Lesson 3: Pipe Types and Size Requirements

As discussed in Lesson 2, both plastic and copper pipe is available for plumbing. These two types of pipe come in several varieties and sizes. Installing plumbing involves not only choosing the best type of plumbing for a particular purpose, but also choosing the correct pipe size. The size of the pipe must be adequate to deliver the required amount of water at the proper pressure.

Pipe Types and Characteristics

Plastic pipe is the most popular plumbing material for agricultural structures. This type of pipe is durable and readily available in various forms and diameters that will meet practically any plumbing need. It is less expensive than copper pipe. Plastic pipe is also easier to work with and requires few specialized tools or skills. However, plastic pipe does have a few disadvantages. It is brittle and more easily broken at low temperatures. Also, plastic pipe is crushed more easily than harder metal pipes.

Five basic types of plastic pipe are available: Polyvinyl Chloride (PVC), Chlorinated Polyvinyl Chloride (CPVC), Acrylonitrile-Butadiene-Styrene (ABS), Polyethylene (PE), and Polybutylene (PB). Each type of plastic pipe has a unique chemical composition that affects its suitability for a given situation.

Polyvinyl Chloride - PVC is the common rigid white plastic pipe seen around construction sites. The pipe size most generally used is either 1 inch or ¾ inch in diameter; the pipe comes in lengths of 10 to 20 feet. It is used for cold water supply and waste disposal lines. This material is not recommended for hot water because of its chemical composition.

Chlorinated Polyvinyl Chloride - CPVC is similar to PVC pipe, but it is off-white or cream in color and is recommended for temperatures up to 180 degrees Fahrenheit. This pipe is most commonly found in ½- to ¾-inch diameters and 10 foot lengths. CPVC is a common choice for hot water lines. Although CPVC will work for cold water supply lines, it is seldom used for this purpose because it is more expensive than PC pipe and because using similarly colored pipe for hot and cold lines can become confusing when installing or repairing lines.

Acrylonitrile-Butadiene-Styrene - ABS is a hard black plastic pipe used mostly for drain and sewer lines. It is commonly available in sizes ranging from 1¼ inches to 6 inches in diameter and in lengths of 10 to 20 feet.

Polyethylene - PE is a flexible black plastic tubing that comes in coils from 100 to 300 feet in length. It is available in diameters of ¾ inch to 2 inches. Since it cannot withstand heat, PE is only useful for handling cold water. PE is primarily used for installing underground water service lines.

Polybutylene - PB is a flexible plastic pipe, usually gray in color, that is available for use with cold or hot water. It is most commonly ⅜ inch or ¼ inch in diameter. PB has the advantage of being flexible enough to go around corners or objects without having to be cut and joined together with fittings. For this reason, it is useful in place of copper for fixtures such as sinks or toilets. Polybutylene pipes have been problematic, however; they have been prone to leaks, especially around fittings. Manufacturers are attempting to correct this problem with new types of connectors.

The other type of pipe most frequently used for plumbing is copper. Copper pipe is very durable. The pipe is not difficult to work with, but it does require more skill and specialized equipment to perform tasks like soldering joints and fittings. The main disadvantage of copper pipe is its cost; the pipe is more expensive than plastic pipe. Thicker pipe contains more copper and is more costly, although it is also more durable. The pipes are available in two forms, hard and soft copper; hard copper pipe is rigid, while soft tubing is flexible. Depending on the type of pipe, copper pipe is available in sizes of ¼ inch to 12 inches in diameter. Hard copper generally comes in 20-foot lengths, while soft copper comes in coils varying in lengths from 45 to 100 feet. Pipes come in four weights: K, L, M, and DWV.

K - This pipe has the thickest walls of the four types. It is available in hard and soft copper forms. For the purposes of identification, K is color coded green. The pipe is used for underground supply lines.

Figure 3.1 - Plastic Fittings

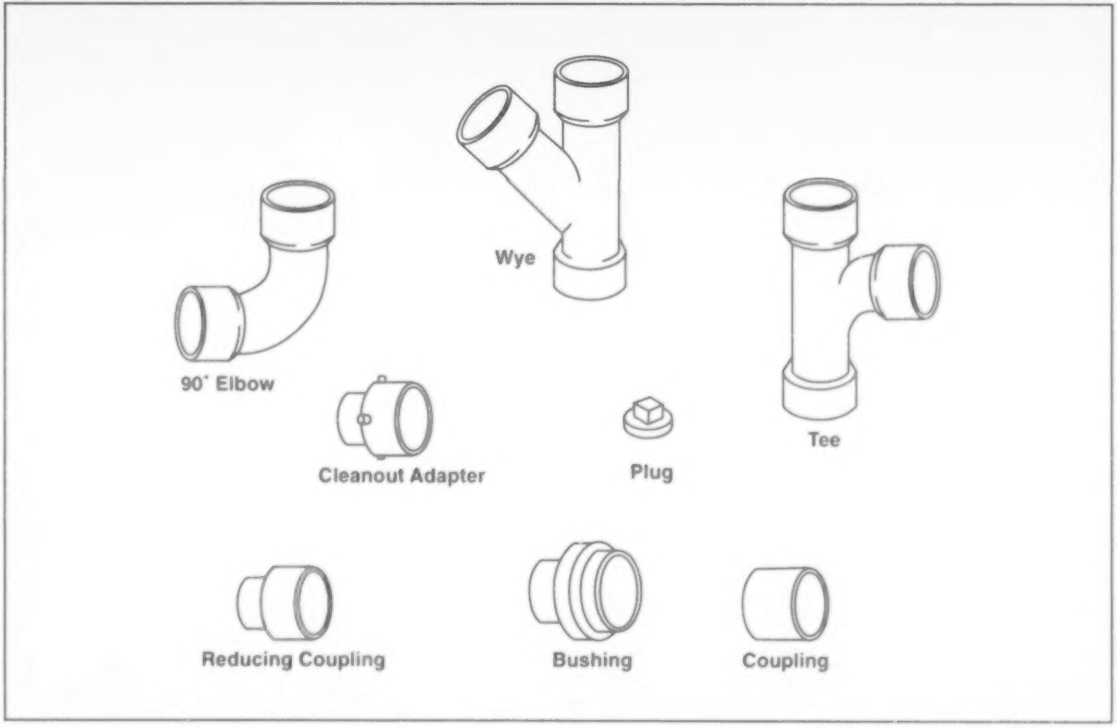
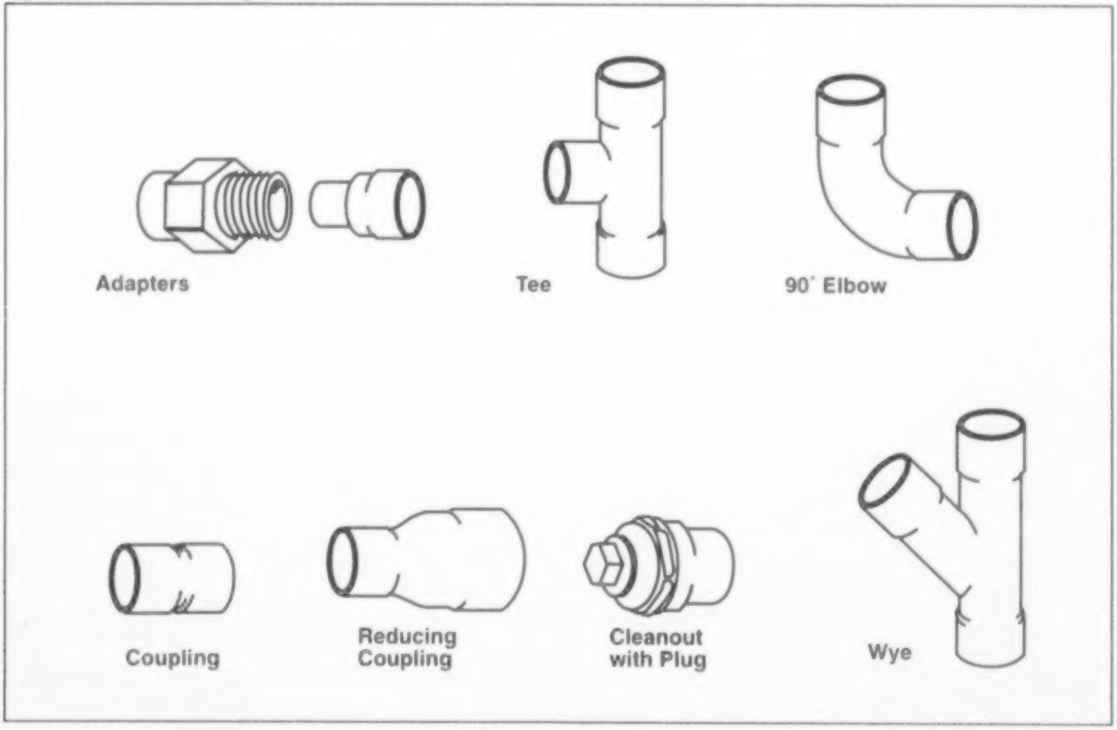

Wye
90° Elbow
Tee
Cleanout Adapter
Plug
Reducing Coupling
Bushing
Coupling

Figure 3.2 - Copper Fittings


Adapters
Tee
90° Elbow
Coupling
Reducing Coupling
Cleanout with Plug
Wye

L - This type of pipe is slightly thinner than K and is available in hard or soft forms. Its color code is blue. Type L must be used above ground; it is used for general interior work.

M - Type M is slightly thinner than L. It is available in hard form only and is color coded red. Common uses are for above ground interior water supply, waste, or drainage lines.

DWV- DWV is the thinnest of the four types of copper pipe and is available only in the hard form. It is color coded yellow. This type of pipe is used above ground for drainage, waste, or vent (allowing gases in a waste line to escape) pipes.

Pipe fittings join pipes together and allow them to branch, change direction, be reduced in size, or be capped. Fittings called elbows allow the pipe lines to make 45 or 90 degree turns. Couplings join two sections of pipe of the same size. Reducers connect pipes that differ by one size, such as a ½-inch pipe and a ¾-inch pipe. Bushings reduce the size of the opening in a large pipe into which a smaller pipe passes; in contrast to reducers, they allow a broader range of pipe sizes to be joined and can be used with larger pipe sizes. A tee is a branch fitting that makes a 90 degree turn; a wye makes a 45 degree turn. Cleanouts are fittings that allow entry into the pipe line in the event a clog occurs. End caps block off the end of a pipe. Figures 3.1 and 3.2 show different types of plastic and copper fittings.

Pipe Sizes

All types of copper and plastic pipe are referred to by their diameter. Standard pipe sizes are ½, ¾, 1, 1¼, 1½, 2, 2½, 3, 4, 5, 6, and 8 inches. Pipe sizes are measured to the nearest fraction of an inch. The measurement most often approximates the inside diameter (ID) of small pipes of less than six inches and the outside diameter (OD) on large pipes. Most pipes, especially plastic pipes, will have the size and either ID or OD clearly marked. If in doubt, the end of a section of pipe can be measured.

Pipe Size and Flow Rate

After choosing a particular type of pipe, the next step is determining the proper pipe size for a given use. The size of pipe can be affected by many factors. The distance the water travels from the source to the end point, the pressure the water is under, the slope the water must travel up or down, the resistance of the surface of the pipe, the number and sharpness of the bends in the pipe, the number of fittings, and expansion and contraction of the pipe due to temperature all affect the amount of water delivered in a given situation. Because of the complexity of these factors, overestimating pipe size and water delivery rates in order to avoid problems is common.

For complex construction projects where the pipes must be sized exactly to deliver the desired flow rate, two pieces of information are required, the desired flow rate in gallons per minute and the amount of resistance due to friction between the water and the surface of the pipe. The desired flow rate can be determined by adding the typical flow rates for different water outlets that will be operating at the same time. Once this number is obtained, a pipe size must be selected that will allow the desired flow rate while limiting losses in pressure due to friction to 5 pounds per square inch or less. Information on typical flow rates and friction losses for different sizes and types of pipe can be obtained from plumbing supply centers.

A less exact method is frequently used for less complex structures like homes and agricultural buildings. Pipe size tables like that shown in Table 3.1 on the following page can be obtained for different types of pipe. They are used to choose the correct pipe size given the pipe system length and the desired flow rate. When determining the pipe size needed, ten percent must be added to the measured length of the system to make up for losses due to fittings. For example, if the length of a system is 380 feet, the length to look at is 418 feet (380 + 38). For a system with this length and a flow rate of 5 gallons per minute, the correct pipe size is 1¼ inches.

Summary

Plastic and copper pipes are most commonly used in plumbing today. These materials are available in a variety of forms and sizes. The size of the pipes used in a plumbing system is determined by looking at the amount of water needed and the amount of friction between the water and the surface of the pipe.

Table 3.1 - PVC Pipe Size Table

Distance in Feet*	Flow Rate (Gallons Per Minute)						
	2	3	5	7.5	10	15	20
Up to 25	½	½	¾	¾	1	1	1
50	¾	¾	¾	1	1	1¼	1¼
75	¾	¾	1	1	1	1¼	1½
100	¾	¾	1	1	1	1¼	1½
150	¾	¾	1	1	1¼	1½	1½
200	¾	1	1	1¼	1½	1½	2
300	¾	1	1	1¼	1½	2	2
400	1	1	1¼	1½	1½	2	2
500	1	1	1¼	1½	2	2	2
600	1	1	1¼	1½	2	2	2
700	1	1¼	1¼	1½	2	2	2½
800	1	1¼	1½	1½	2	2	2½
900	1	1¼	1½	2	2	2½	2½
1,000	1	1¼	1½	2	2	2½	2½
1,500	1¼	1¼	1½	2	2	2½	2½
2,000	1¼	1½	2	2	2½	2½	3
3,000	1¼	1½	2	2	2½	3	3

*Add 10 percent to the measured length to account for losses due to pipe fittings.

Credits

Annis, William H. *Basic Plumbing Skills.* Athens, Ga: American Association for Vocational Instructional Materials (AAVIM), 1989.

McConnell, Charles. *Plumbers and Pipe Fitters Library.* Vol. 3, *Water Supply • Drainage • Calculations.* New York: Macmillan, 1989.

Phillips, Richard E. *Farm Buildings: From Planning to Completion.* St. Louis: Doane-Western, 1981.

Lesson 4: Measuring, Cutting, and Connecting Pipes

Plumbing nearly always involves measuring, cutting, and joining of pipe and tubing. This lesson will describe how to perform these essential tasks properly.

Measuring Pipe

Most of the pipe used in plumbing is rigid, so accurate measurements are essential for the pipe system to connect properly to outlets and appliances. The first factor to consider in measuring pipe is the distance from the water source to the desired outlet along the exact path that the pipe will take. Another consideration is the length of the pipe being installed. The distance from the source to the outlet is divided by the length of the pipe. For a measurement of 50 feet, for example, five 10-foot lengths of pipe seem appropriate. However, the fittings used to join the sections of pipe also must be considered; they increase the length of the system. The amount of increase is dependent on the size of fittings and any angles made by the fittings. The length of the pipes may have to be adjusted to account for the fittings.

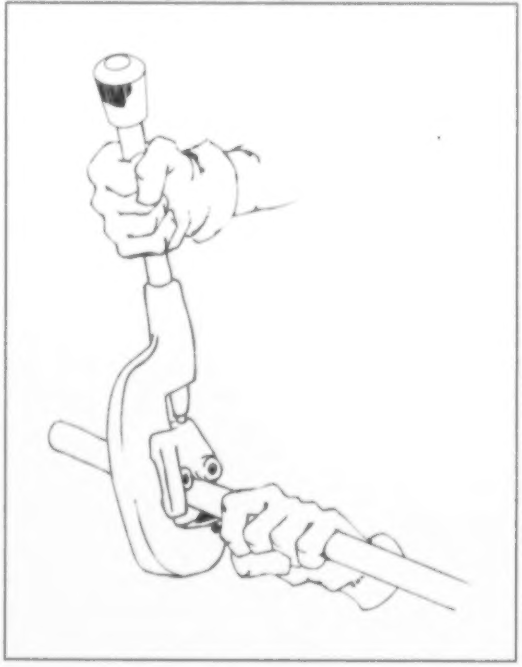
Cutting Pipe

Pipe may be cut easily with the proper tools. As discussed in Lesson 2, these tools consist of pipe cutters, which may be used with either plastic or copper pipe, and hacksaws for use on plastic pipes.

Pipes must be carefully measured before being cut. The pipe is measured with a tape measure or folding ruler. An allowance for the fittings must be made when determining the length of the pipe. The length to which the pipe will slide or screw into the fitting needs to be added to the length that will run between fittings. The point where the pipe should be cut is marked with a pencil; the marking should extend all the way around the pipe to make it easier to find. Because accurate measurements are necessary for correct installation of plumbing systems, measurements should be made to the nearest 1/32 of an inch regardless of the type of pipe used.

After the pipe has been measured, it can be cut. To use the wheel-type cutters for copper pipe illustrated in Lesson 2, the cutter is opened by turning the handle until the pipe will fit between the wheel and roller. The pipe is placed in the base of the cutter and the handle is turned until the pipe touches the cutter wheel. The wheel is positioned on the point where the pipe is to be cut, and the handle is turned to press the wheel into the pipe. The tool is rotated around the pipe once, and then the handle is tightened and the tool is rotated again. This process is repeated until the pipe is cut. Figure 4.1 shows a wheel-type cutter in use.

Figure 4.1 - Using a Wheel-Type Cutter



A hacksaw is used to cut plastic pipe. If possible, the pipe is first placed in a vise to hold it still. The hacksaw blade is positioned on the mark for cutting. The hacksaw is pulled backwards, placing no pressure on the pipe, and then the blade is brought forward with pressure exerted to cut into the pipe. While sawing, the saw should be held at a 90-degree angle to the pipe, resulting in a square cut. Excessive force should not be exerted on the pipe while cutting. The process is repeated until the pipe is sawn through completely.

Any burrs, or sharp edges, and ridges left on the inside or outside of the pipe from cutting should be smoothed. With copper pipe, a small file, sandpaper, or a special reaming tool can be used;

sandpaper or a knife is used for plastic pipe. Smoothing these cuts helps to insure a good watertight seal between the fitting and the pipe.

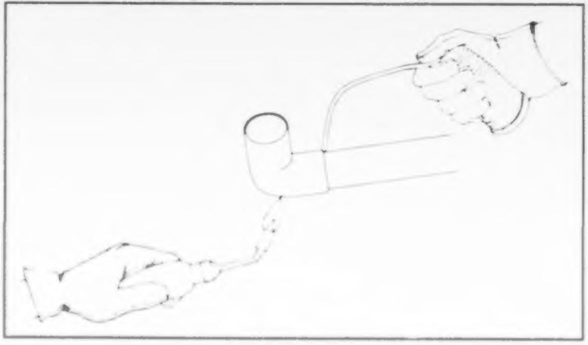
Joining Pipe

Several different methods are available for joining pipe. As discussed in Lesson 2, plastic pipes are joined using cements. Copper pipes can be soldered together; copper tubing may also be joined using flare joints.

Joining plastic pipe using cements is a relatively easy process. The end of the pipe and the fitting must be smooth and clean. A chemical cleaner is the best way to clean this material. Once the fitting and pipe end are clean, they are covered with an even coating of cement on the pipe and fitting socket. This cement usually acts quickly, so the pieces need to be joined together immediately and firmly to make sure they are seated correctly. The pipe should be given a quarter turn to make sure it is seated securely. A solid and permanent joint will be created after the pipe and fitting are held together ten seconds to a minute. A line of cement should appear all the way around the joint, indicating that enough cement was used. Joints created using cement are very durable and solid, and any mistakes will have to be cut out, since separating the joint is not possible without destroying the pipe and fitting. The directions and recommendations for cements should always be read before they are used.

Copper pipe is generally joined by soldering copper fittings to the pipe. This procedure is simple, but doing it well requires practice. First, the end of the pipe and the fitting must be clean; very fine sandpaper or emery cloth works well. The copper should be shiny and free of any oils or dirt. The use of soldering material, which looks like heavy wire, is enhanced by a compound called flux that removes impurities. Flux may need to be placed on the pipe before soldering, although some types of solder contain a core of flux or acid that makes additional flux unnecessary. Since different kinds of solder have different compositions and recommended uses, the manufacturer's instructions should be read before the material is used. To solder, the fitting is placed on the pipe or tubing, and a propane torch is used to heat first the pipe and then the fitting around the entire joint until the solder melts when touching the joint. The solder is held to the rim of the fitting, as shown in Figure 4.2, and is drawn into the joint.

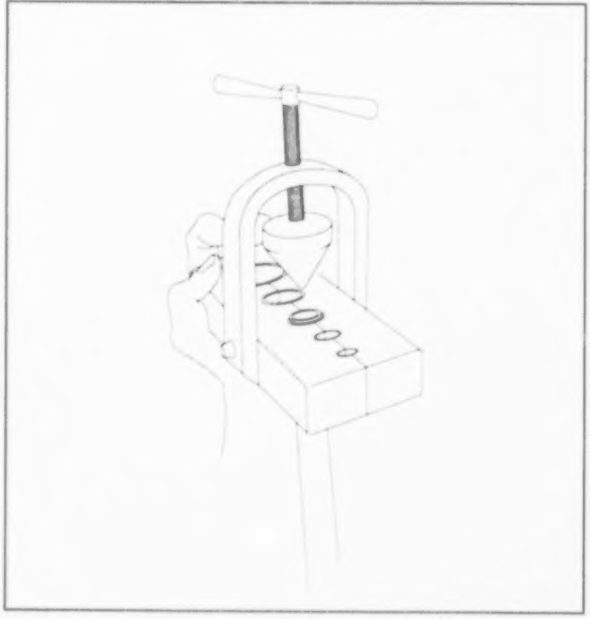
Figure 4.2 - Applying Solder



The solder is applied around the joint until it is found around the entire rim of the fitting. The excess solder is wiped away while the pipe and fitting are still hot. As the solder cools in the joint, it bonds the pipe and fitting like a metal weld, providing an excellent seal.

Sometimes soldering cannot be used to join copper tubing because of the heat of the propane torch and the location of the pipes or because the joint should not be permanent. In such cases, flaring is used to join the tubing. Making a flare joint involves using special tools to make the end of the tubing flare outward to join the fitting. After the tubing has been cut, a flare nut is placed on the tubing. The pipe is flared using some type of flaring tool. One common type of flaring tool is a yoke and screw flaring tool (see Figure 4.3), used

Figure 4.3 - Using a Yoke and Screw Flaring Tool



with different sizes of pipe. The tubing is placed in the correctly sized opening of a flaring block and secured in position with the end of the tubing extending above the block about ⅓ the depth of the block chamfer. The yoke of the flaring tool is placed over the block, with the compression cone centered over the tubing. The screw is tightened to form the flare between the block and the cone; the screw should not be turned too far, since the tubing may split. When the flare is finished, the fit of the flare is checked to the seat of the flare nut. The fitting is then placed against the flare, and the nut is tightened to hold it in place.

Summary

Precise measurements of the distance between a water source and outlets, pipe, and fittings are necessary to determine the lengths of the pipes needed for a plumbing system. The next step is cutting the pipe to the appropriate length using the proper tools. When pipe has been cut, smoothed, and cleaned, the pipes and fittings are joined using one of several methods, depending on the type of pipe. When properly installed, fittings should be durable and watertight.

Credits

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Lesson 5: Protecting Water Pipes from Freezing

A well-designed and constructed plumbing system will seldom freeze. Freezing is preventable if certain factors are considered when planning pipe installation, and methods of insulating and heating pipes are available to prevent freezing. If lines do freeze, thawing the pipes without causing damage is possible if it is done correctly.

Factors to Consider When Installing Pipe

Running water lines underground below the frost line is a proven method of preventing freezing in the lines. How deeply the pipes are laid depends on the frost line in the area. The average frost line in Missouri is 36 inches. Pipes should be below the frost line. Most people install their pipes a foot below the frost line to help prevent freezing. A county Extension office or reference materials from a local library can provide information on the exact depth necessary in an area.

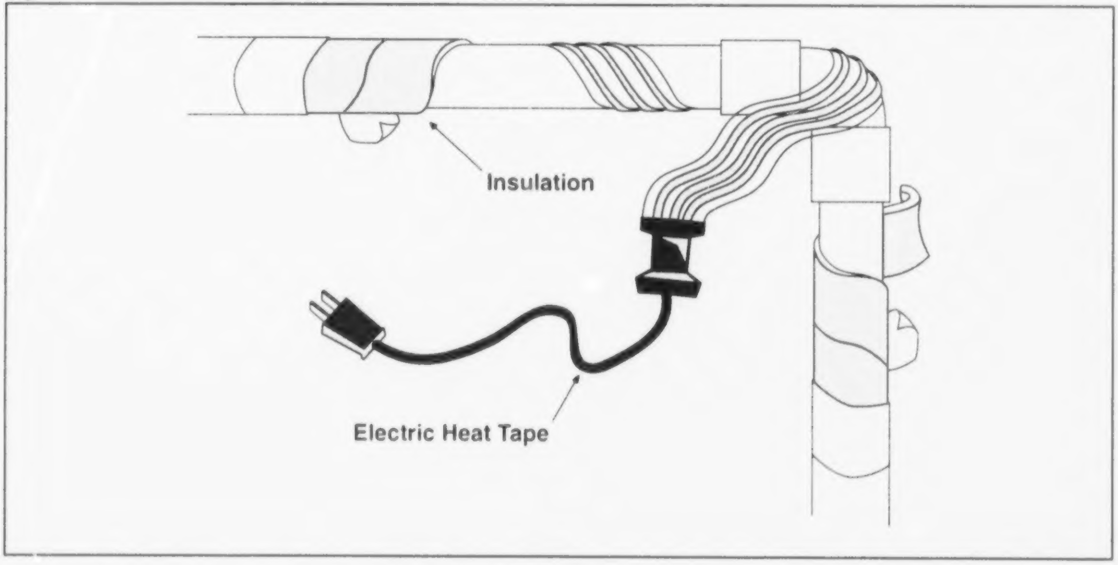
When installing plumbing in and around a structure, the design of the plumbing system should take into account the potential for freezing. Designing the system so that pipes are placed in interior rather than outside walls can protect them from freezing. If pipes must be exposed to cold temperatures, certain measures can be taken to avoid freezing. Insulation should be used around pipes placed near exterior walls. Insulation with an R factor of 6.5 to 8 offers substantial protection. The insulation should be carefully wrapped, with the ends butted together tightly and joined with tape. Frost-free faucets should be used outdoors; their design prevents water from remaining in the section of pipe extending above the ground when the faucet is not in use. If pipe is installed in an area subject to freezing, a drain valve should be added. The valve allows water to drain out of the pipe, preventing damage due to freezing.

Methods to Prevent Freezing

Where water lines come to the surface, a significant threat of freezing exists, and protective measures should be taken. In cold weather, any exposed pipe should be wrapped in waterproof insulation; with extremely cold temperatures, even frost-free faucets should be insulated. Protecting the pipe from direct winds will also reduce the threat of freezing. One way to protect the pipe would be to create a temporary shelter around the exposed pipe using stacked hay bales.

When conditions heavily favor freezing, other measures may protect interior pipes. Supplying at least minimal heat to the inside of the structure using any appropriate heating system will greatly reduce the risk of pipes freezing inside the building. Another method of preventing freezing involves using electric heat tape. The heat tape is placed along the pipe, which is then wrapped in insulation to hold the heat close to the pipe, as shown in Figure 5.1. The tape carries an electrical

Figure 5.1 - Electric Heat Tape



current through it to supply heat, much like an electric blanket. Heat tape can be wired either with a timer set to turn it on and off at certain times or with a thermostat that activates the tape at a designated temperature.

Figure 5.1 - Electric Heat Tape

Allowing the water to run continuously can also prevent freezing. Monitoring a water line's output is useful if freezing is likely. As ice forms in the pipe, the water pressure begins to drop. The line should be opened a little so that the water runs continuously. Running water is much more resistant to freezing; the water may also help remove ice that has already formed in the line. If the pressure returns to normal, the water should be allowed to drip or trickle from the faucet until the temperature rises to a safe point.

Thawing Frozen Water Pipes

Should pipes become completely frozen and obstructed, a careful inspection of all exposed water lines will be necessary. If any breaks are found, the water to that section of the line or to the entire system should be turned off. The break will have to be repaired, usually by cutting out the broken section and putting in a new pipe with fittings, before turning the water on again.

To thaw frozen pipes, the frozen section of the pipe needs to be heated. Professional plumbers frequently use torches for this task. However, this practice can be dangerous. If the flame comes in contact with combustible material, a fire can result. With the pipes frozen, water may not be available to douse even a small fire. Also, heating the pipes in one spot too quickly can cause the water to boil, creating enough pressure to cause the pipes to explode. If the pipe is too hot to touch, too much heat is being applied. A flame should never be applied directly to a plastic pipe, since it will melt.

Safer methods can be utilized to heat pipes. Electric heaters, hair dryers, heating pads, and electric blankets are often effective, although these devices should only be used after evaluating if any danger of electrical shock exists when using them around water lines. Placing embers or charcoal briquettes in an appropriate container near the frozen pipes may be useful for thawing exterior pipes.

Summary

With frozen water pipes, prevention is by far the best solution. Pipe lines should be buried below the frost line. The design of the plumbing system should also prevent freezing, by avoiding placing pipes near exterior walls or using insulation where appropriate, using frost-free outdoor faucets, and installing drain valves. If pipes are likely to freeze, they should be insulated or heated if possible, or the water may be allowed to run continuously. Frozen lines must be inspected for leaks before applying heat to the frozen section. Thawing must be done safely, without starting a fire, causing pipes to explode, or creating a situation where electrical shock is possible.

Credits

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Lesson 1: Fencing Basics

Fences are used extensively in agriculture. Most fences are designed to contain or restrict the entrance of animals, but they may also be built for appearances. This lesson will introduce some fencing basics, such as legalities, safety, and construction and repair.

A Legal Fence

Because fencing obligations, responsibilities, and boundaries have been and continue to be a source of conflict, laws have been enacted to help define responsibilities and liabilities concerning fences. Although local counties and townships had their own regulations, the state of Missouri was legally an open range until 1969. Property owners had the responsibility of fencing animals out of their property to avoid damage. However, in 1969, Missouri changed the law to a closed range system. This law requires livestock owners to confine their animals and makes them liable for damages caused by unrestricted animals. This law covers horses, cattle, swine, and similar stock.

The changing laws brought about the need for defining what a fence is and the minimum acceptable standards for a fence. Questions, such as who is responsible for the construction, maintenance, or replacement of a shared fence, can be complicated. If disputes cannot be settled by the owners, the local courts may have to determine what should be done. A lawful fence may be defined in one of two ways, depending on the local regulations. Most counties have laws based on either the state's general law or the optional Fence and Enclosure Act of 1963. Adoption of the Fence and Enclosure Act suspends the provisions of the general statute.

Under the general law, a fence is a sufficient enclosure if it meets the following standards.

- Hedges are at least 4 feet high.
- Fences composed of posts and rails, post and palings, posts and wire, posts and boards, or palisades are at least 4½ feet high with posts firmly in the ground not more than 8 feet apart.
- Fences consisting of woven wire, wire netting, or wire mesh are at least 4½ feet high with posts not more than 16 feet apart.

Other fence structures satisfying the definition of a lawful fence are described as well, including worm (rail) fences, turf fences, and stone or brick fences. The law states that all fences should be constructed to resist horses, cattle, swine, and similar stock.

If a county has adopted the optional provisions of the Fence and Enclosure Act of 1963, a lawful fence is defined as follows:

- A fence not fewer than four boards per 4 feet of height, each board to be spaced no farther apart than twice their width and to be fastened to posts not more than 12 feet apart with one stay. A stay is a vertical member attached to each board or wire forming the horizontal members of the fence.
- A fence of four barbed wires supported by posts not more than 15 feet apart with one stay or 12 feet apart with no stays.
- Any fence that is at least equivalent to the types of fences in the other categories.

Common Fencing Tools and Safety Measures

Fences come in a variety of forms and materials. Board, rail, panel, woven wire, barbed wire, and smooth wire fences are all common on farms. Most fences can be erected with using a few basic tools: a hand-operated or power-driven post hole digger or auger, a metal rod for packing earth around posts, a metal post driver or a post maul for driving wooden posts, a hand ax or chain saw, fence stretchers, a hammer, a tape measure, fencing pliers, a roll of nylon string to help lay out straight lines, and a level to help assure that posts are set straight. Using these tools safely is important, since fencing can be dangerous work.

Protective clothing, such as steel-toed boots, heavy pants, gloves, and eye protection, is very beneficial when using any of these tools. Gloves are especially useful and should be worn to prevent blisters and other injuries to the hands. Building fences is usually hot and hard work; heavy clothing and boots are not always comfortable under these conditions. However, this clothing can help avoid an injury.

A hand-operated post hole digger consists of two blades, each with a separate handle, that are joined by a hinge. Soil is removed by digging the blades into the earth and then pulling the handles outward and lifting the digger upward. When using this tool, the target area for digging should be clear and free of large rocks that can produce flying chips. Maintaining good posture while operating this tool will help reduce back strain or injury.

Power-driven post hole diggers, which have an auger that bores a hole into the ground, come in a variety of styles, such as one- or two-man gas-powered units or tractor-powered units attached to the front or back of a tractor. To operate these safely, the manufacturer's recommendations should be followed. Keeping any loose clothing away from the auger can prevent serious injury. Augers are powerful and can easily mangle a person's arms or legs if clothing gets caught in the auger as it twists. Hearing and eye protection should be used.

The metal rods used for packing earth around posts are close to 6 feet in length. They may weigh 20 to 40 or more pounds. One end is pointed to chip at or break hard material in a post hole, while the other end is flat for packing earth and rocks. Protective glasses can prevent injury to the eyes from rock chips. Gloves and steel-toed boots can help avoid injury to the hands and feet from the heavy rods.

Metal post drivers are weighted metal tubes with a sealed top and handles on the sides. The open end of the post driver slides over the top of the post and is raised up and slammed down on the post to drive it to the correct depth. Good posture and control while lifting the post driver can help avoid back injury. Gloves will help prevent blisters.

A post maul is a large sledgehammer-type tool for driving sharpened wooden posts. They often weigh 10 or more pounds. Anyone using this tool should make sure that everyone working in the same area is out of striking distance. Gloves should be worn to protect the hands, while eye protection should be worn to prevent injuries from stray flying material.

A hand ax is sometimes needed to clear an area of limbs or brush before building a fence. Safety glasses, gloves, and steel-toed boots are needed for safety.

A chain saw is used to clear areas for fence construction or to cut wooden posts or rails to the desired length. Hearing protection, eye protection, gloves, and steel-toed boots will increase safety when using this tool.

Fence stretchers are a tool that pulls wire taut before it is fastened to the fence posts. While the tool itself may not be dangerous, it should be used with caution, because wire that has been stretched too tightly may break and cause injuries, as discussed in the next section.

Safety Measures for Fence Construction

Certain precautions can be taken to help reduce injuries when building fences. To safely construct a fence, the clothing and safety accessories mentioned above should be used; a hat and a shirt with long sleeves may provide additional protection. If possible, fence construction should not involve working alone in an isolated area, since help may be necessary if an injury occurs. The tools used for construction of the fence should only be used as designed and recommended by the manufacturer. Fence construction may involve heavy lifting, so proper lifting techniques, such as keeping the back straight and using the leg muscles to help move the weight, should be used. Heavy loads should also be held close to the body to help reduce strain. Unexpected hazards such as wasps, bees, snakes, and plants such as poison ivy are also to be considered and avoided if possible. Caution should be used when working with wire, which commonly causes cuts. Barbed wire is particularly hazardous.

Because wire must be stretched before fastening it to the posts to make it rigid, overstretching may occur, causing the wire to break and whip back against or around the person stretching it or someone else. Wearing gloves and eye protection is a must.

Summary

Fencing is hard but necessary work. A good fence is required for livestock, both to keep the animals safe and to prevent them from damaging other people's property. Any fence built should meet the definition of a legal fence for its owner to avoid liability for damages. When building a fence, caution is necessary for safety. Using basic fencing tools safely, wearing protective clothing, and taking precautions can help make fencing safer.

Credits

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Lesson 2: Setting and Bracing Posts

As indicated by the descriptions of a legal fence in the last lesson, strong, properly spaced posts are an important part of a fence. This lesson describes corner posts, line posts, and braces and explains how to install them.

Materials and Tools for Wood Posts and Braces

The basic materials needed when installing wood posts and braces are the posts and braces themselves, large nails, such as 16d tempered ring shank pole barn nails, wire for wire braces, and staples. Wood corner posts are often chemically treated to resist rotting and may last for 10 to 30 years. They are generally 6 or more inches in diameter and about 8 feet or more in length, since they will need to be set 3 to 3½ feet into the ground. Wood line posts are 2½ inches to 6 inches in diameter, with a diameter of 5 inches preferred for most fencing jobs, and 5½ to 8 feet in length. Most of these posts are chemically treated. Braces are the crossed or diagonal pieces of material running between the post being braced and the next post in line or a wood, metal, or concrete anchor. The most common brace material is a wood brace pole approximately 5 inches in diameter; they are commonly 8 feet in length, but longer braces of 10 or 12 feet add more structural support to the brace structure. Large nails attach the brace pole to the posts. The best type of wire to use for wire braces is 12½ gauge high tensile smooth wire. Staples are used to attach the wire to the posts.

Site preparation tools are necessary to install wood posts. The site preparation tools needed depend on the site, since all brush, old fencing, trees, and large rocks are removed. In some cases, filling low areas and excavating elevated ones is beneficial. An ax may be needed in many cases. A wheelbarrow and chain saw can be useful also. Sites requiring more preparation may call for heavy equipment, such as a tractor with a brush-hog type mower and a grading blade or a bulldozer.

Once the site is prepared, layout and construction tools are necessary. Tools needed to build the fence include a post hole digger, shovel, and hoe. Some of the tools used in site preparation, such as a wheelbarrow and chain saw, may be used again. Layout tools include a tape measure 100 feet or more in length and a level.

Locating Wood and Steel Anchor-and-Brace Assemblies

Much of a fence's strength depends on the quality of the anchor-and-brace system, whether the posts are steel or wood. If the braces fail, the fence will too. Also, the appearance of the fence is important; corners and brace assemblies are the focal points and should be constructed neatly.

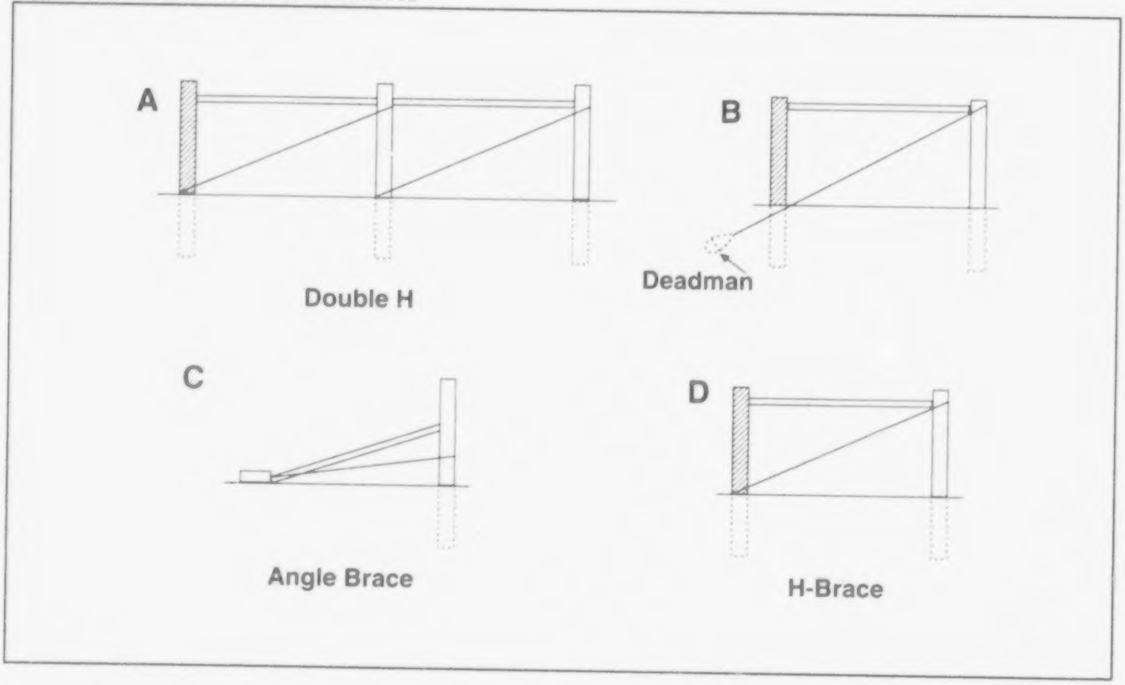
Fence corners generally require anchor-and-brace assemblies, sometimes referred to as fence structures. Brace assemblies may also be placed at points along the fence line to compensate for the effect of stresses exerted on the fence. The location of these structures will depend on the type of fence (barbed wire, woven wire, high tensile smooth wire, etc.), topography of the ground, type of ground (dry, rocky, swampy), length of the fence run, and bends in the fence line.

Installing Anchor-and-Brace Assemblies and Brace Wires

Figure 2.1 on the following page shows some different configurations used for corners or braced-line post systems. The most common type of fence structure is the H-brace, which consists of two posts set in the ground with a brace pole between them. A variation of this type of assembly is the double H-brace, which adds an additional post and pole to the structure. The double H-brace is used for longer stretches of fencing and stretches where higher tension or stress loads will be placed on the structure. A third variety is the angle brace, which utilizes a single post, a brace pole, and a flat rock or formed concrete pad. The brace pole is placed at an angle to the post, with one end set into the post and the other fitted to the top of the rock or pad. This type of structure is commonly used when slight bends or turns are required in the fence line. Another assembly has an anchor called a deadman near the corner post. The anchor is driven in the ground or placed in concrete. A brace wire attaches the deadman to the post, adding rigidity to the assembly.

The first step in installing the common H-brace assembly is setting the posts in place. The end or corner post is placed first. Placing the post will involve digging a hole to an appropriate depth, setting the post in the hole, and filling in the hole

Figure 2.1 - Anchor-and-Brace Assemblies



around the post with dirt or gravel. The second brace post can then be put in place in line with the first at the desired distance. Because of the angles formed by an H-brace, a longer brace pole will provide more structural strength to the fence. The industry standard is 8 feet in length, but when a single H-brace is needed due to ground conditions or other factors, using a 10- to 12-foot brace is preferable.

Once the posts are properly set and tamped in place, a chain saw is used to form a notch for the brace pole in each post. The notches should be perpendicular to the fence line, so the flat surface at the base of the notch is at a 90-degree angle to the fence wires. Typically, a good height for the bottom edge of the brace pole is 36 to 42 inches from the ground, but the height should be determined by the spacing of the fence wires, so the brace does not interfere with wire placement. For structural soundness, the brace pole should be placed as high as feasible on the structure.

The next step is to install the twist wire. The wire is wrapped twice completely around each of the posts that the twist wire will connect. The direction of the fence pull will determine the placement of the wire. The direction of the pull depends on which section of fence coming into the brace is longer and will exert more stress on the brace post. The twist wire is loosely stapled low on the brace post farthest from the longer stretch of fence and just above the brace on the post next to the length of fence being braced. As much slack as possible is removed from the twist wire by pulling on both ends, and the wires are spliced together.

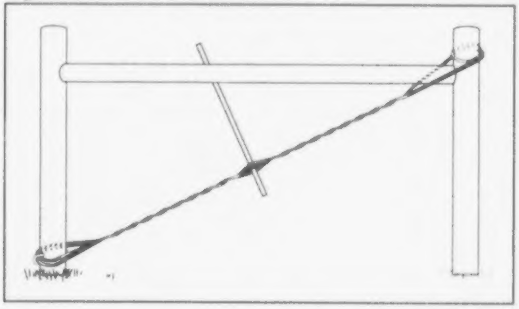
After some tension is put on the structure, the ends of the brace pole are nailed to the posts using the 16d nails ring shank nails. Four nails are used at each end, one on top, one on each side, and one on the bottom.

Next, a twist stick is inserted between the wires. The stick may be a 1-inch wood dowel, fiberglass rod, or a short section of 2" × 4" or 2" × 2". The twist stick should be a minimum of 20 inches in length. Rotating the twist stick will put tension on the wires.

The wires are twisted so that when the assembly is finished the stick will be pulled against the brace pole on the opposite side from where the wire is attached. As tension is placed on the twist wire, the structure should begin to move in the opposite direction from the pull of the fence. A good rule of thumb is to move the end post approximately ½ to ¾ of an inch out of plumb away from the direction of pull. Less tension may be necessary if a gate will be attached to the end post, thus providing more balance against the pull of the fence, or on short fence runs where the fence wire has less tension.

Once the structure is tensioned into place, the twist stick is attached to the brace pole. The preferred method is to drill a ¼-inch hole through the twist stick in line with the brace and then drive a 16d galvanized nail through the stick and into the pole. This method is preferable because the nail can easily be removed to tension the wire again. A completed H-brace is shown in Figure 2.2.

Figure 2.2 - H-Brace Construction



Installing Wood Line Posts

Wood posts are common for corners and braces, but they are becoming less popular for line fencing. They require more maintenance and have a shorter life span than steel, which has made their use selective.

Before the posts can be installed, the fence line must be laid out. Laying out the fence line can be done by having one person stand behind a corner post and another person move down the fence line toward the next corner post. The person moving down the fence line holds a movable post, or sighting pole. The person at the corner post directs him or her to a position that lines up the corner post, the post being held, and the next reference point, which may be either the corner post or, for hilly ground, the farthest point that can be viewed clearly. The spot is marked for reference in aligning the posts.

The installation of wooden line posts is a relatively simple process. The first step is to measure off the line post spacing. The placement of wooden line posts is determined by the type of fence, the amount of pressure that will be placed on the fence by livestock, dips and rises in the ground, and whether steel, fiberglass, or other types of posts are also placed in the fence line. For field fencing, line posts are commonly 14 to 20 feet apart, while 8 to 16 feet is typical for more confined lots. A tape measure may be used to measure out the exact spot for each post, or the distance between them may simply be estimated by pacing out the distance. An individual may lay out a 100-foot measuring tape and walk the length of it, counting the number of steps taken. Dividing 100 by the number of steps can give a relatively accurate length pace, which may be used for post layout.

Then the ground line is marked on the posts; line posts are usually set at least 30 inches into the ground. The holes are dug to the proper depth, and the posts are set in packed dirt. A level may be used to check the posts' plumbness. An alternative method of placing wood posts is sharpening and driving them into the ground with a post maul or a hydraulic post driver mounted on a tractor. Posts that are driven into the ground are stronger than those that are hand set.

Special considerations for setting any line posts are topography and ground conditions. Wet areas will typically require a longer post driven deeper into the ground to provide stability for the fence. Posts set in low areas may need special bracing to keep them from lifting out of the ground. One method is to nail a pressure-treated 2" × 6" about 24 inches long horizontally to the bottom of the post. Another method is to drive a steel t-post 4 to 5 feet long as deep as possible at an angle next to the post and attach a wire or chain to the t-post and wooden post.

Tools Needed for Braces and Steel Posts

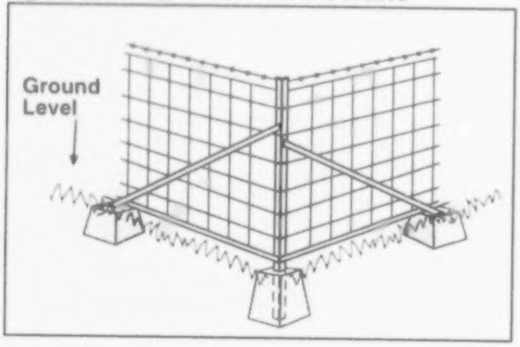
As wood posts become less common, steel posts are growing in popularity. Steel posts have several advantages over wood; they are fireproof, economical, and easy to install and maintain.

Steel posts are commonly available in lengths of 5 to 8 feet. The same type of post may be used for both corner and line posts in a light duty fence. However, often the corner post is a metal pipe 5 or 6 inches in diameter that has been filled with concrete.

Some of the same tools used with wood posts are needed with steel posts. Tools for clearing a fence line, such as a chain saw, ax, or heavy equipment, may be used as described previously.

Some additional tools are required to work with steel posts. A metal post driver is an indispensable tool for setting posts. Some metal fence systems use bolts and nuts to attach braces. A set of wrenches or a socket set will meet these needs. Other metal brace systems are welded in place, thus requiring a portable arc welder. Metal posts vary in configuration and sometimes require specific fasteners that are supplied with the posts. Most fasteners are easily attached with fencing pliers. If a special tool is needed for the fasteners, it should be available from the retailer. Metal corner posts and braces are often set in concrete, as shown in Figure 2.3. Tools needed for working with concrete include either a portable cement mixer or a wheelbarrow, a shovel, and buckets or a hose to supply water.

Figure 2.3 - Metal Corner Post and Braces



Installing Steel Post-and-Brace Assemblies

The first step in installing steel post-and-brace assemblies is to dig the anchor post hole. The hole for the anchor posts should be 3 feet deep. The post hole will provide more stability if it is approximately 20 inches in diameter at the bottom and 18 inches in diameter at the top. The ground line is then marked on the post.

The next step is to bolt or weld the braces to the anchor post. Braces are generally set at angles of approximately 45 degrees. Holes are then dug where the braces touch the ground. The hole must extend 6 inches below the frost line. The depth varies depending on the geographical region, but the hole should be a minimum of 18 inches deep and is preferably deeper, usually 2 to 3 feet.

When the holes are ready, the concrete is placed around the post and braces. The top of the concrete should be molded to slope away from them to direct water away from the post and prevent problems caused by freezing. Finally, a level is used to make sure the post is plumb.

The anchor-and-brace system for corner and line posts is basically the same. The only difference is that with line posts the braces are attached to extend directly along the fence line rather than form a 90-degree angle.

Installing Steel Line Posts

Installing steel line posts is simpler than working with wood line posts. The first step is measuring the line post spacing and aligning the posts. The ground line is marked on the posts, which are set 2 to 3 feet deep. They are then driven to the proper depth using a steel post driver.

Factors Affecting Gate Installation

Fences would be of little use without a gate to allow entrance and exit. The size and weight of the gate will greatly affect the fence and brace structure construction. A heavy gate will provide a counter force to the pull of the fence, so the weight of the gate should be taken into account when tensioning the brace structure. Also, gates should not be hung from lone posts, which are single posts without bracing, because they will not give enough support. A larger post, 7 inches in diameter or more, should be used for the gate post. Gates should be hung in line with the fence structure, providing maximum support for the gate. If double gates are hung, a brace assembly must be installed on both sides of the opening.

Summary

The first step in building a fence is installing the posts. Both wooden and steel posts are commonly used for fences. Two types of posts make up fences: anchor-and-brace posts and line posts. Anchor-and-brace assemblies are necessary at fence corners; the placement of other fence structures along the fence line will depend on the type of fence, topography of the ground, type of ground, length of the fence run, and bends in the fence line. Because the size and weight of gates will affect the fence, these factors must be taken into account when installing a gate.

Credits

Ramsey, Dan. *The Complete Book of Fences.* Blue Ridge Summit, Pa.: TAB Books, Inc., 1983.

University Extension agricultural publications, University of Missouri-Columbia.

G1191: Selecting Wire Fencing Materials
G1192: Constructing Wire Fences

Lesson 3: Barbed and Woven Wire Fences

Barbed and woven wire fences are common in agriculture. This lesson describes the basics of building these two types of fences, including the materials and tools needed and the process of installing the wire.

Materials and Tools for Barbed Wire Fences

The materials needed to erect a barbed wire fence are barbed wire and staples or metal clips for attaching the wire. Barbed wire is fencing material made of wire strands twisted together with wire barbs placed at various intervals. The main characteristics to look for when purchasing barbed wire are gauge, number of barbs, wire coating, and type of wire. Barbed wire is manufactured and sold by gauge, a number representing the diameter of the wire. A lower number corresponds to a larger diameter. The most common gauges in Missouri are 12½ and 14 gauge. The configuration of the barbs on the wire will vary slightly by manufacturer, but two and four points are the most common. Barbed wire will usually be coated with zinc or aluminum to help it resist rust. Both coatings are effective, but aluminum will last longer under most circumstances. Barbed wire comes in either soft wire or high tensile wire. The wire is fastened to posts using either staples for wood posts or specially designed metal clips for metal t-posts.

Usually fences will use only wood or metal posts, but if the land is relatively flat and free from rocks, they may have alternating metal and wood posts. Metal posts will last longer than wood posts because they will not rot, but they are not as strong as wood posts. By alternating posts, costs are reduced with a minimal reduction in the strength of the fence.

Barbed wire is selected by evaluating the cost and needs of the operation. Heavier gauges are more expensive, and wire with 4-point barbs is usually more costly than wire with 2 points. Post spacing, the number of strands used, the size of the area to be fenced, and the type of livestock to be contained are all factors to consider when choosing wire. For example, a small lot for cattle would benefit from five strands of 12-gauge wire with 4-point barbs. A sturdy fence would be necessary in an area where cattle would be pushing against the fence often. This type of fence may also require closer post spacings, and the use of more wooden posts rather than metal t-posts. A fence for cattle on a range area works well with four strands of 2-point 14-gauge wire. Posts may be spaced more widely for this type of fence, and metal t-posts would work well for this situation.

Relatively few tools are necessary to build the fence. A claw hammer, fencing pliers, and fence stretcher are sufficient.

Laying Out Barbed Wire

Barbed wire fence installation is not complicated, but it can be dangerous because of the sharp barbs. When working with barbed wire, observing all safety practices is a must.

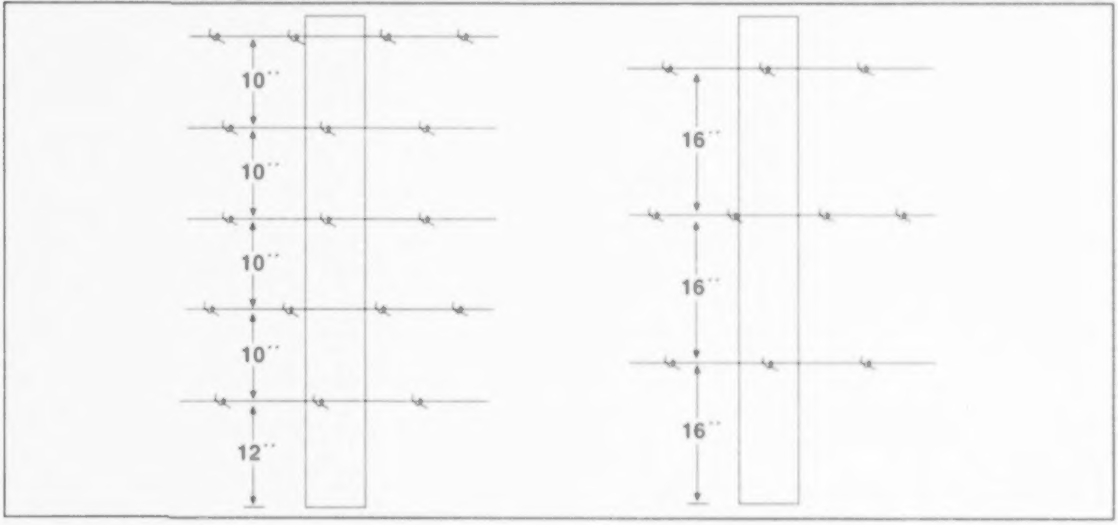
Once the posts are in place, the bottom strand of the wire is wrapped around the corner post two or three times and stapled securely. The end of the wire should be twisted tightly around the wire strand. This connection to the post must be very secure for the wire to be stretched without coming loose. The number of strands of wire used determines the height of the bottom strand. Figure 3.1 shows an example of some typical spacings.

Having attached the first strand at the desired height, the wire may be unrolled along the fence line on the stock side of the posts. The length of wire unrolled depends on the topography, fence layout, and the position of fence brace structures. Barbed wire comes in rolls of wire a quarter mile long, and the entire length of the wire can be laid out at once under the proper conditions. Using short stretches of wire is more costly, because more time and more materials, most notably for brace assemblies, are required. More braces are necessary because the fence should be braced at each end of a stretch of wire. The same procedure is used for each strand, from the bottom to the top. The wire should be placed as close as possible to the fence line. Walking the fence line and moving the wire into place may be necessary. This practice helps to remove excess slack prior to stretching the wire.

Stretching Barbed Wire

The next step in putting up the fence is stretching the wire. Most fence stretchers are simple and effective. Many designs are available, including

Figure 3.1 - Wire Spacing



systems that operate on winches, pulleys, or ratchet systems. One common tool has a clamp on one end to grasp the wire while the handle operates as a lever against a post to stretch the wire. Tractor-operated or hydraulic stretchers are available for larger fence construction projects.

To operate a stretcher, it must be attached to the wire being stretched. The stretcher can be attached to a solid object in line with the wire, usually the post of a brace structure, or a piece of equipment. Short stretches should not be made to line posts because these posts are not secure and will pull over easily. For longer stretches, the wire can be stretched and spliced in the middle to distribute the pull more evenly throughout the wire. The stretcher then connects to the wire only. Slack is taken up with the stretcher, and then the wire is spliced once it is at the proper tension.

The length of wire to be stretched at a time depends on the topography of the area and the stretching tools. Hilly areas require stretching short sections at a time to keep the wire level. A rule of thumb is to stretch from 5 to 20 rods at a time; a rod is 16½ feet. Stretching longer sections of wire will take less time.

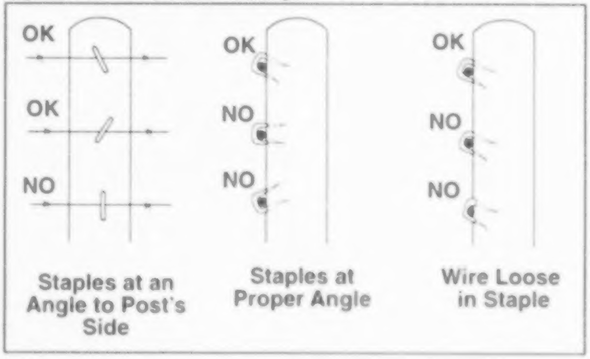
Using the stretcher to take up the slack, the wire is slowly stretched to the point of being relatively tight and straight. The wire should not be too tight to allow expansion and contraction of the metal wire due to temperature changes. Wire should never be stretched too tightly, because overstretching may break the wire. Depending on the length of the stretch, it may be necessary to walk along the fence line and untangle the wire.

Attaching Barbed Wire

Once the fence is tight, the wire is attached to the post while the stretchers are still in place. The end of the wire should be long enough to wrap completely around the post twice and then be tied off back onto the wire itself. The wire generally is then stapled to the post to prevent slippage if the tie works loose.

Staples are used to attach wire to wood posts. Although most fencing pliers have a hammering surface, a hammer is useful if much stapling is required. When attaching the wire, the staples are angled as shown in Figure 3.2, with the staples set diagonally at a slight downward angle to resist the

Figure 3.2 - Staple Positioning



pull of the wire. The staple is then driven into the post. Staples should not be driven in so tightly that they and the wire become embedded in the post. The wire needs room as it expands and contracts with changes in temperature.

If steel posts are used, the wire is attached using metal clips supplied with the posts. These clips are used to hold the wire against the post. Fencing pliers are most commonly used to position the clips, but some types of posts require a specific tool supplied by the post retailer to attach them.

Woven Wire Materials and Tools

To erect a woven wire fence, the appropriate type of wire and fasteners are necessary. Woven wire is a type of fencing material in which wires are connected together to form a mesh. The horizontal wires are continuous throughout the fence. The vertical wires, or stays, are attached in one of two ways. One method has short pieces of wire wrapped into a knot at each horizontal wire, so the stay is not one piece of wire. This variety is referred to as hinge lock wire because the knot resembles a hinge. Another method has a continuous stay with short sections of wire forming the knots that attach the stay to the horizontal wire. This type of woven wire is referred to as stiff stay wire.

Woven wire comes in either soft or high tensile wire. The traditional soft wire fencing typically has wire of a heavier gauge for the top and bottom wires, while high tensile wire uses wires that are all the same gauge.

An industry standard system of labeling indicates the size of the woven wire fencing. A three-number designation identifies the number of horizontal wires, the height of the fence, and the distance between vertical stay wires. For example, a designation of 10-47-6 would identify wire that has 10 horizontal wires, is 47 inches tall, and has stays spaced 6 inches apart.

When selecting woven wire, the chief factors to consider are the gauge, protective coatings, and the application, which may affect the pattern, weave size, or height of the wire chosen. Like barbed wire, woven wire is sold by gauge. The lower the number assigned, the larger the diameter of the wire is. Zinc, aluminum, and sometimes vinyl coatings extend the life span of woven wire. Many patterns and weave sizes are available, and the fencing comes in a variety of heights, commonly 20 to 60 inches. When selecting woven wire, the application is critical. For example, chickens would need a higher, lighter weight fence with smaller openings than fencing for hogs.

Woven wire may be used with either wood or metal posts. Wood posts require staples for fastening the wire, while metal posts call for wire clips.

The tools needed to put up the fence are much the same as for barbed wire. They include a claw hammer, fencing pliers, and a woven wire stretcher. A woven wire stretcher works the same way as any other wire stretcher. However, because woven wire comes in dimensional form, stretching the top, bottom, and middle of the wire at the same time is important. A shovel may also be needed to trench elevated areas in the fence line that will interfere with the bottom wires.

Laying Out a Woven Wire Fence

When laying out the wire, the first step is unrolling the wire past the corner post on the side of the post to which the wire will be attached. Enough wire should be laid out to wrap around the post once. Three or four stays should be removed to wrap around the post cleanly.

Stays are removed in one of two ways, depending on the type of woven wire. For hinge lock fencing, the stay is cut in the middle of each block. Then, while using pliers to hold the knot, the ends of the cut wire are grabbed and twisted in the opposite direction from the knot. The sections of the stay wire should slide off the horizontal wire. For stiff stay wire, the small knot wire that holds the vertical stay in place is cut.

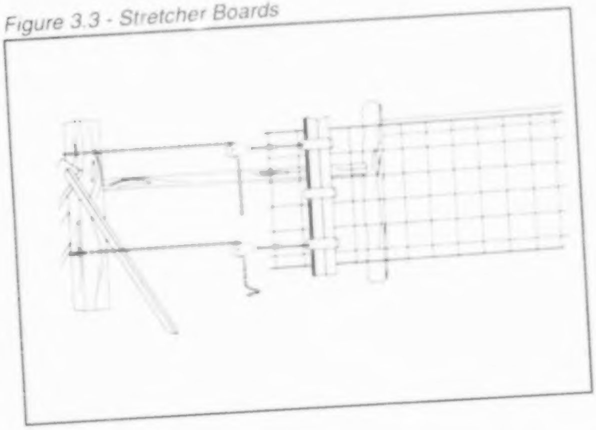
After removing the stays, the wire is set to the desired height against the anchor post. The wires are then wrapped around the post and tied off by splicing the end of each wire onto itself. This practice will make a solid connection for stretching.

The wire is rolled out either to the brace structure that it is to be attached to or to the point where it will be spliced onto another roll. Rolls of woven wire are 330 feet long. The maximum length that can be stretched at one time is a quarter mile, which will consist of four rolls of wire. For short stretches of wire, the wire will be rolled out past the brace structure to be stretched. If two or more rolls are required, one roll is fastened to a post at each end, and then the wire rolls are stretched and spliced in the middle. An alternative method is to attach one end of the first roll to a post and then tie the other end to the next roll. The entire length is tightened at the same time. However, the wire will not be as tight as it would be if it were stretched in the middle.

Stretching Woven Wire

Wire stretching can be done in several different ways, although most stretchers operate on either a pulley system or a leverage system. Woven wire can be stretched using stretcher boards; one type of stretcher board is shown in Figure 3.3. Stretcher boards can be made of either wood or metal. Wood stretcher boards are made of 2" × 4" boards that are bolted together to hold the woven wire. Prior to stretching the wire, the position of the holes for the bolts are laid out and marked on the boards; they should be positioned to fall between the horizontal wires. The boards are clamped together, and the top of the boards is marked. The holes are then drilled through the boards. The holes are generally 5/16 to ⅜ of an inch in diameter, depending on bolt size. Typically, four evenly spaced holes are needed for woven wire that is up to 5 feet tall, with more holes needed for taller fences. Metal stretcher boards can also be purchased from retailers that carry fencing supplies. On these stretcher boards, bolts for tightening the stretcher boards have been welded into position. Typically, metal stretcher boards are purchased if a large amount of fencing will be done.

Figure 3.3 - Stretcher Boards



To stretch short stretches of wire from one brace structure to another, the stretcher boards are attached to the wire a few feet past the post to which the wire will be tied off. The boards should be attached in line with one vertical stay. If the boards are attached at an angle, the fence will not stretch evenly. The ends of a heavy chain are wrapped around the top and bottom of the boards. A cable winch-puller, or come-along, is attached to the chain and to a secure point, such as a truck, tractor, or another fence anchor post. If two come-alongs are available, two chains can be used with the stretcher boards instead of one.

The fence should be tensioned slowly. When the fence is properly tensioned, ½ to ⅔ of the tension bump should be removed. A tension bump is a small bend in the woven wire that acts as an aid in determining if the wire has been tightened enough. If the tension bump is completely straightened, the wire is too tight. While the fence is being stretched, it may need to be shaken to free it from snags.

Attaching Woven Wire

When the wire has been stretched, each wire is tied off, one at a time. The wire is cut at a point far enough past the post for the wire to wrap around it. Any stays that might interfere with the post should be removed. The wire can then be wrapped around the post, tied off, and stapled tightly to the post. Finally, the stretcher boards are removed.

The horizontal wires are then attached to the line posts. With wood posts, each wire is stapled tightly, so that the staple and wire are set into the post. Staples are placed crosswise with a slight downward angle, as shown in Figure 3.2. If metal posts are used, wire clips supplied by the retailer of the posts are fastened according to the manufacturer's recommendations.

Generally, for fences up to 4 feet tall, only five staples or clips are needed per post. Taller fences may require a few more fasteners. The top and bottom wires are attached at every post, while the other fasteners should be staggered on different wires at each post.

Summary

Barbed wire and woven wire fences are common types of fences in agriculture. The basic materials and tools needed to build these types of fences are similar: barbed or woven wire, fasteners, a claw hammer, fencing pliers, and a fence stretcher. In each case, the wire is laid out along the fence line and attached to the brace structure, stretched properly, and then attached to other brace structures and the line posts.

Credits

Ramsey, Dan. *The Complete Book of Fences*. Blue Ridge Summit, Pa.: TAB Books, Inc., 1983.

Selecting Wire Fencing Materials (G1191). University Extension agricultural publications, 1993.

Lesson 4: High Tensile and Electric Fences

Barbed wire and woven wire fences are only two of the types of fences that may be found on agricultural operations. Other common fences are high tensile and electric fences. These types of fences have some advantages over fences made of barbed or woven wire. This lesson describes those advantages and explains the components of high tensile and electric fences and how they are constructed.

Advantages of High Tensile Fencing

High tensile wire gets its name from its tensile strength, since it can take a large amount of stress before breaking; this strength is its chief advantage. The wire is stronger and more durable than standard wire of the same gauge, which means that lighter wire can be used. A 13½-gauge high tensile wire is approximately equal in breaking strength to a 12½-gauge regular wire.

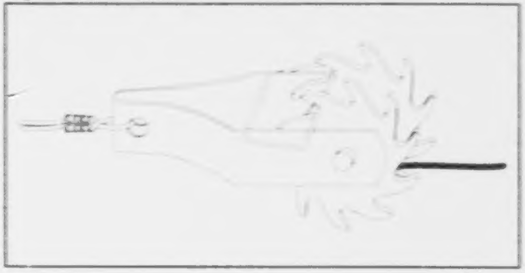
High tensile fencing also has other advantages. Because the strength of the wire makes it less prone to breakages, high tensile wire has a longer life span and lower maintenance requirements. It is also versatile, coming in a variety of forms, including strand wire, woven wire, and more decorative wire that is vinyl coated or covered with a board-like vinyl panel. This type of wire is easier to handle than barbed or woven wire, since it does not have dangerous barbs and is lighter than woven wire. High tensile fencing can easily be electrified. Finally, high tensile wire's strength makes it a good choice to replace barbed wire when the animals being fenced need protection from the barbs. A good example is show animals, where the owner wishes to avoid scars that could disfigure the animal.

Components of High Tensile Fencing

The basic components of high tensile fencing are similar to those for standard wire: high tensile wire, posts, and fasteners. Wood or steel posts may be used, although it is better not to use steel posts with an electrified fence. Wood posts may be either rounded or square. The corner posts should be at least 5 inches in diameter. Brace posts should be at least 4 inches in diameter, and line posts should be at least 3½ inches in diameter. The wire is attached to the post using fasteners, either staples for wood posts or metal wire clips for steel posts. Staples should be 1¾ to 2 inches long to provide adequate holding power and keep them from pulling out of the post.

Some additional materials are used for high tensile fencing. Spacers called battens, stays, or droppers can replace some of the line posts in holding the wire in place. They are made of wood, steel, or fiberglass. Permanent in-line strainers (see Figure 4.1) or tension springs can maintain the tension of the wire over time. In-line stretchers are used for longer stretches of wire, while tension springs are only needed on short stretches of 500 feet or less.

Figure 4.1 - Strainer

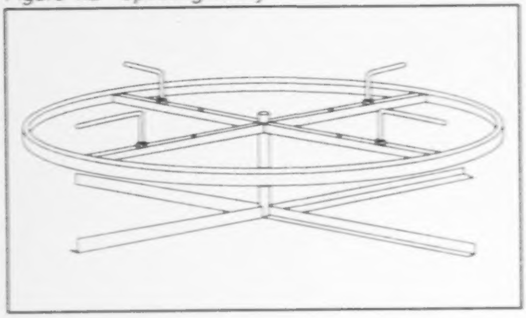


Construction of High Tensile Fences

Some tools are needed for constructing high tensile fences. A wire spinner feeds out the wire. When using this tool, the wire is laid onto a rotating table, and L-shaped brackets then lock the wire in place and hold it as the wire uncoils. High tensile wire is springy, and attempting to work without a spinner generally leads to kinks. Also, high quality wire cutters, preferably ones designed for working with high tensile wire, should be used for cutting.

In construction of high tensile fences, the posts must be installed before working with the wire. The first step is to set the anchor post and brace structure. Double brace structures should be used because they can hold more tension, with loads up to 9,000 pounds, which is appropriate for longer runs of wire and large livestock. Next, the line posts, spacers, and line brace structures should be set. Line brace structures should be included in the fence at appropriate intervals and at the top and bottom of slopes. The line posts should be set 2½ feet into the ground for stability. The distance between the line posts will vary with the purpose of the fence. For large pastures with little

Figure 4.2 - Spinning Jenny



pressure on the fence, a good rule of thumb is placing the line posts 16 feet apart, with shorter distances used for smaller areas. The use of spacers allows the posts to be set further apart.

When the posts are set, the wire is laid out, stretched, and attached. The wires are attached working from the bottom to the top. The best method for putting up high tensile wire is to work from the middle. A spinning jenny, which is a device that aids in unrolling wire from the spool (see Figure 4.2), should be placed somewhere in the middle of the span. The first wire is pulled from the spinner to one brace structure. It is wrapped around the post twice and tied off. At the spinner, the wire is cut, and an in-line strainer is attached to the end of the wire. The wire is then pulled from the spinner to the other brace structure and tied off. At the spinner, about 3 feet of wire is run past the strainer, and then the wire is cut. The end of this wire is placed in the strainer, and tension is taken up by turning its drum. After applying some tension to the wire, it should be loosely stapled in place. Once all the wires are in place in the fence line, the wires are tightened to the proper tension and stapled to the posts, with the wire left slightly loose in the staples so it can move as it expands and contracts due to weather conditions. To complete the fence, the wires are attached to the spacers in the fence line.

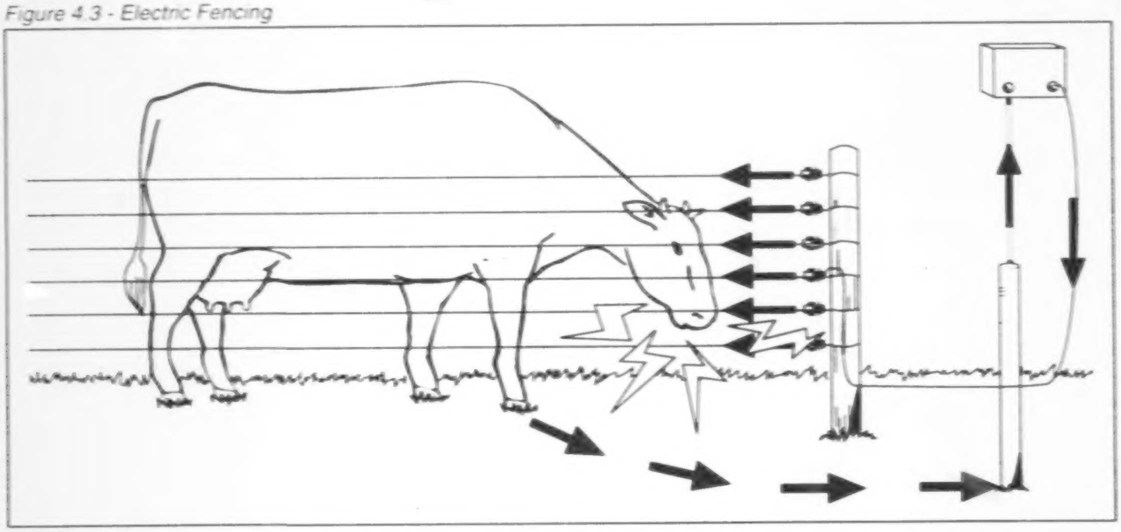
Typically, high tensile wire is electrified. If the fence is not electrified, more fence posts and stays are necessary because the posts should only be 6 to 10 feet apart in order to keep the animals in. With the posts farther apart, livestock will basically walk through the fence.

Advantages of Electric Fences

Unlike the other types of fences discussed in this unit, an electric fence is a psychological barrier, not a physical one. It operates using an electric fence charger that converts electricity into a pulse that travels along an insulated fence line. When an animal touches the wire, the current flows from the fence line, through the animal, and then through the earth to the ground system to complete the circuit, as shown in Figure 4.3. The brief shock that results keeps the animal from putting pressure on the fence. Livestock eventually become trained and avoid the fence.

Electric fences have several advantages. They are low in cost, requiring fewer materials and less labor to construct than other types of fences. Because electric fences use fewer materials and

Figure 4.3 - Electric Fencing



do not have to be stretched, they are quicker and easier to construct than other types of fences. Another advantage is that they are versatile; electric fences can be used for many types of animals. Because the animals generally leave the fence alone, it has a long life span. Also, no physical damage occurs when animals are shocked.

Depending on the purpose of the fence, electric fences can require a lot of maintenance. Plants growing to the point where they touch the wire may ground the system and prevent it from working effectively. Limbs falling across the wire and touching the ground will have the same effect. Livestock and wild animals, such as deer, often break smaller strands of wire when they accidentally run into them. Most fence chargers, which supply electricity to the fence, indicate whether the fence is electrified with an indicator light or by making a regular popping sound. To catch potential problems, a producer should check the charger often and walk the fence line.

Components of Electric Fencing

An important component of an electric fence is the wire that forms the fence. The best wire to use for electric fences is 12½ gauge or 14 gauge high tensile or soft wire. A smaller gauge will constrict the flow of electricity, decreasing the efficiency of the fence. High tensile wire is preferable. For temporary fences, poly wire is a useful alternative; poly-wire is a stranded polyethylene wire specifically designed for electric fences that has smaller wire conductors embedded in it.

Two other fence components are a fence charger (see Figure 4.4) and one or more ground rods. Most fence chargers convert power from a 120-volt electrical system or a battery, usually 6 or 12 volts, into the charge sent along the fence. A ground rod serves as a connection between the charger and the ground, allowing a completed circuit to be made.

Posts are also needed for electric fences. Generally, wood posts at least 5 or 6 inches in diameter are used. Steel posts may also be utilized, although good insulators are a necessity to keep them from conducting electricity. Small fiberglass rods 3 to 5 feet in length are sometimes useful when constructing a temporary electric fence. These rods will not conduct electricity and do not require insulators.

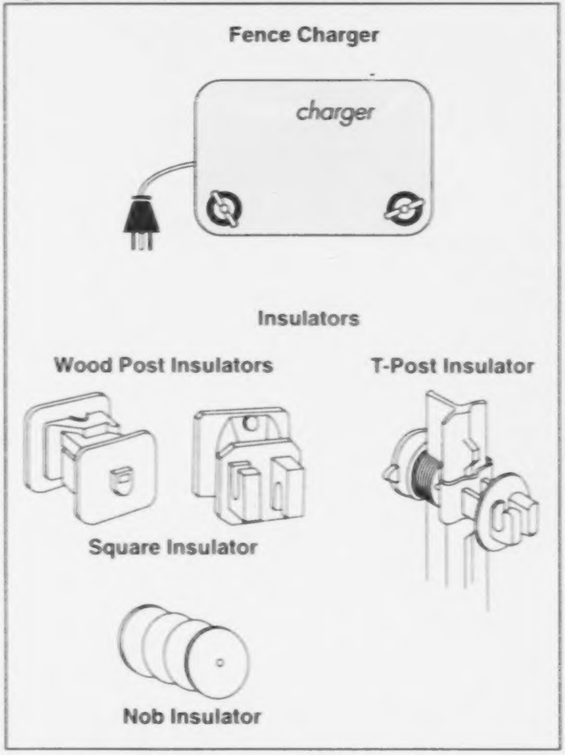
Insulators are nonconducting wire holders that attach to the posts to hold the wire, keeping it from making a connection with the earth. Many different designs are available, as shown in Figure 4.4. For tie-off points at the end of the stretch, specialized terminal insulators made of ceramic or plastic are used. For wood line posts, brightly colored nail-on plastic insulators are often used to hold the wire, which either wraps around the insulator or passes through a bracket. An insulator called insultube is used with high tensile wire; insultube is plastic tubing that slides onto the wire and is stapled to the post. T-post insulators clip onto steel posts and hold the wire in a bracket.

A simple gate may be easily constructed using a special insulated gate handle. These insulated handles are usually made of plastic with a spring attached. One end attaches to the wire and the other has a hook that connects the fence.

Selecting Electric Fence Chargers

One factor to consider when selecting a charger for an electric fence is the location of the fence, which will determine whether electricity is

Figure 4.4 - Components of Electric Fences



available. The battery types are useful for remote areas where no electrical systems are available. Some units have a solar-powered battery charger built into the charger; the batteries are recharged by sunlight. Where electricity is available, plug-in chargers should be used to take advantage of main line power.

Two related considerations when selecting chargers are the voltage put out by the charger and the length of the fence. Fencers can provide powerful electric charges, commonly up to 30,000 volts. An electric fence that has been correctly constructed can carry a charge of this intensity through miles of wire. Fence chargers generally indicate the amount of voltage they put out and how many miles of fence they can supply with power.

The amount of vegetation around the fence will affect the fence charger chosen. Grass and weeds can rob the fence of some of its power, so a fence charger that could supply power to 20 miles of fence under conditions with less vegetation would not be able to provide that much electricity to a fence overgrown with weeds. Low impedence fence chargers are useful when vegetation is high. This type of charger increases its energy output as power is drained off by plants touching the fence. It can overcome the voltage loss caused by the vegetation.

The species of livestock will also affect the selection of a charger. Less voltage is needed for animals that have thin coats, like horses and short-haired cattle. Animals with thicker coats, like sheep or goats, require higher voltages.

Safety must be considered when choosing a charger. Any charger selected must have been approved by the Underwriters Laboratories or another reputable agency. The current from homemade fence chargers has killed livestock and people.

Constructing Electric Fences

Once a charger has been selected, it should be installed in a dry, protected area, such as a barn or shed. After installation, a ground rod must be set in place and attached to the charger. The ground rod must be in solid contact with moist earth, which may mean driving the metal rod to a depth of up to 6 feet. Drier conditions may require the use of more than one rod. Once the ground rod is in place, a heavy wire is clamped to the top of the rod and the other end attached to the charger's ground terminal. When the posts and wire for the fence are in place, another wire is run from the positive terminal of the charger to the electric fence or to an insulated lead wire to carry the current to the fence.

If permanent posts are in place, they should be used for the fence; if not, the next step is setting the posts in place. The posts should be set to a depth of 3 to 3½ feet. The distance between the posts may vary between 20 and 50 feet. For a temporary fence, the corner and line posts are set to a depth that feels solid. They should not be driven too deep, since they will eventually be moved. Insulators should be placed on the posts at two-thirds of the height of the livestock for which the fence is being built.

Next, the wire is attached to the posts. One or two strands of wire are sufficient for an electric fence. Using at least two wires enhances the functioning of permanent and semi-permanent fences, with one wire serving as the hot wire and the other acting as a return ground in addition to the ground rod. The end of the wire is attached to the insulator on the end post, and the wire is unrolled along the fence line. Soft wire can be stretched with fence stretchers. It is then attached to the insulators. If high tensile fencing is used, the wire should be laid out and stretched as appropriate before it is attached to the insulators.

Sometimes an electric fence is used in conjunction with an existing fence. Placing a single strand of wire close to the bottom of a woven wire fence for hogs or along the top of a barbed wire fence for cattle greatly reduces the animals' contact with the fence.

Summary

In addition to barbed and woven wire, high tensile and electric fencing are options for agricultural operations. High tensile wire is useful where very strong wire is desired. Electric fencing has several advantages, including low cost and ease of construction. In addition to the posts and wire needed for both types of fence, high tensile fencing requires fasteners, spacers, and permanent in-line stretchers, while electric fences call for chargers, ground rods, and insulators.

The basic procedure for building both types of fences consists of setting the posts and attaching the wire, although the details of the process do vary somewhat.

Credits

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Lesson 5: Fence Mending Techniques

Fences are stationary but they do get worn and broken. Repairs are generally simple, requiring a little time and a few materials. However, replacing the fence may be necessary if it is extremely worn or has extensive damage, such as that caused by age, neglect, floods, or tornadoes.

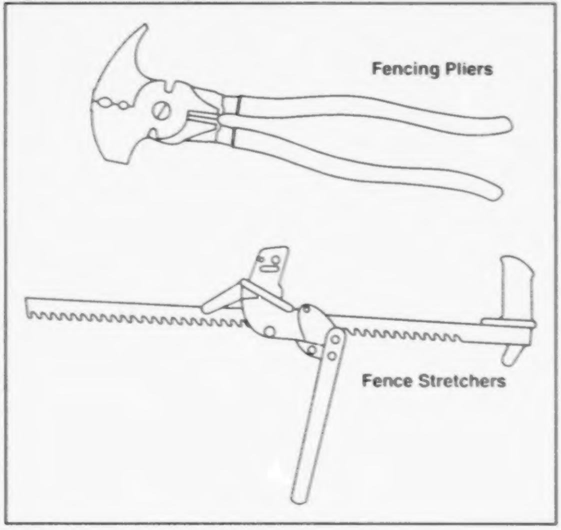
Tightening Fence Wire

Wire will loosen over time due to animals pushing against it and other stresses. If the posts are sturdy, the wire may be tightened in one of two ways. One method involves stretching the wire at a post, while the other involves stretching the wire in the middle of the fence line. In the first method, the wire is detached from an anchor post and loosened at the line posts. The next step is to stretch the wire at the anchor post as discussed in the preceding lessons. It can then be reattached to the posts. The second method involves cutting the wire in the middle of the fence. The fence stretchers are attached at this point, and the wire is stretched. Then the ends of the wire are spliced together. The tightened fence may require new fasteners but will likely give many years of continued service.

Tools for Mending Broken Wires

Fixing fences calls for few tools, including a claw hammer for driving staples, fencing pliers, fence stretchers for pulling the wire together, and specialized splicing tools, such as a sleeve compressor or woven wire splicing tool. Fencing pliers can replace both of these types of tools if only a small amount of repair is needed. However, they are not as convenient or fast as the other tools for more extensive repairs. Fencing pliers and fence stretchers are shown in Figure 5.1.

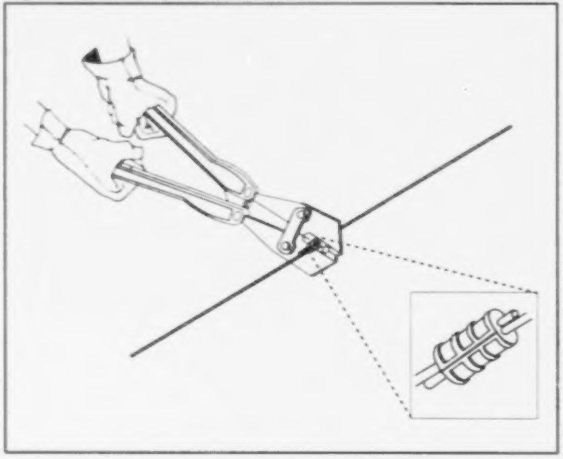
Figure 5.1 - Fencing Tools



Methods for Splicing Fence Wire

For barbed or smooth wire, the preferred method of splicing is a crimp splice using a metal compression sleeve, shown in Figure 5.2. Both ends of the wire are threaded through the sleeve. The sleeve is then pressed together tightly using the fencing pliers.

Figure 5.2 - Compression Sleeve



This type of wire may also be twisted together in a wrap splice with some degree of success. Figure 5.3 is an illustration of one type of wrap slice. One way to make a wrap splice is to make a loop in one wire by wrapping the tail of the wire around the wire several times. The other wire is passed through the loop and then bent back and wrapped around itself several times. This type of repair

Figure 5.3 - Wrap Splice

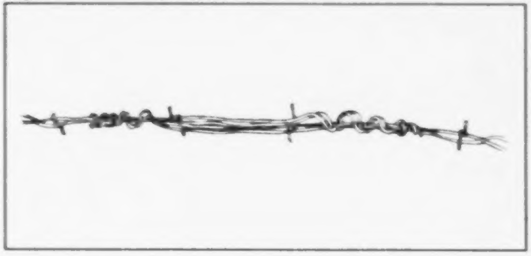
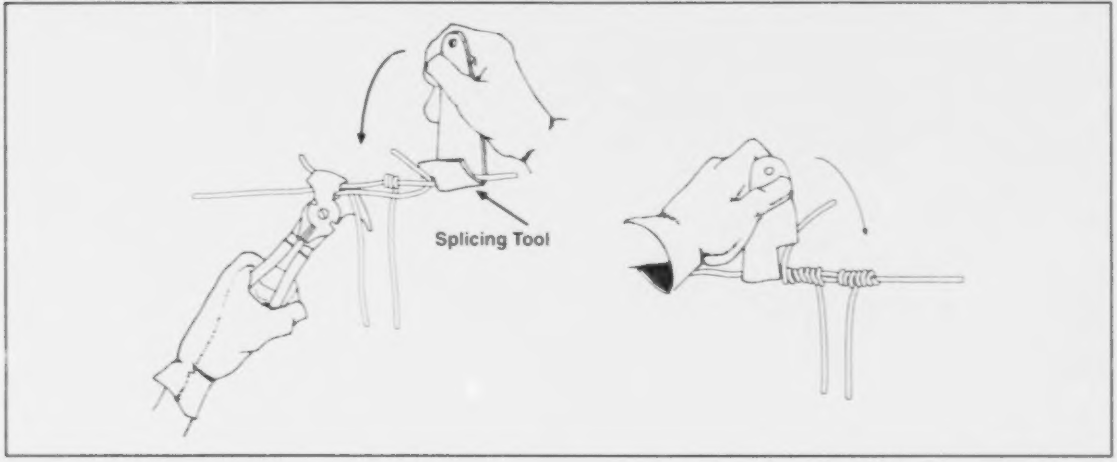


Figure 5.4 - Splicing Woven Wire



seldom produces as tight a bond as a compression sleeve. Lacerations to the hands are also more likely when performing this type of splice.

Repairs to woven wire usually involve a process similar to that shown in Figure 5.4. The wires are simply twisted together tightly using a splicing tool or pliers. These splices may cause lacerations to the hands, so heavy gloves should be worn to perform this type of repair.

Replacing Posts in Existing Fence Lines

Posts that have been broken or damaged by rot should be replaced. The wire is detached from the post, which is then removed from the ground. Sometimes posts can be loosened by rocking them back and forth, and they are then pulled out by hand. Posts may also be removed using post pullers or a jack.

Sometimes a post breaks off at ground level. If possible, the new post is set to one side of the old post. If positioning the post in this way is not possible, digging up the old post is necessary before a new one can be set in the same place.

After the old post is removed, the new one is set in place using the same methods for setting posts that are utilized when a fence is constructed, as discussed in Lesson 2 of this unit. The person setting the posts in an existing fence line should be careful, since she or he will have to work in close proximity to the existing wire.

Summary

Fence repairs are frequent in agricultural settings. Loose fence wires can be tightened either at an anchor post or in the middle of the fence line. Only a few tools are necessary to mend broken wires, which can be fixed using a metal sleeve compressor or by twisting the wire together in some way. If posts in an existing fence line need to be replaced, they should be removed, and new posts set in their place.

Credits

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GLOSSARY

A

Acrylonitrile-Butadiene-Styrene (ABS) pipe: Hard black plastic pipe used mostly for drain and sewer lines.

additive: Substance that is mixed into the concrete to give it special characteristics; also called admixtures.

adhesion: The ability of materials to stick to each other.

aggregates: A raw material of concrete consisting of fine aggregates smaller than a quarter inch in size, typically called sand, and coarse aggregates, called gravel, which are particles larger than one quarter inch in size.

air entraining: The process of trapping small pockets of air in concrete.

air pocket: A hole left in concrete after the curing process is complete resulting from a confined body of air.

air terminal: Lightning rod.

alternating current (AC): Electrical current that alternates, or changes its direction of flow at regular intervals, usually 60 times per second.

ammeter: Device that measures the electrical flow or voltage.

ampacity: The safe carrying capacity of the wire; measured in amperes.

amperage (a): The flow of current through an electrical system; measured in amperes, or amps.

armored cable: Cable with wires enclosed in tough paper overwrap and spiral steel armor.

B

BTU: British thermal unit; one BTU is equal to the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

barbed wire: Fencing material made of wire strands twisted together with wire barbs placed at various intervals.

batt insulation: Insulation provided in rolls of material in precut sections.

batter boards: Boards put in place to mark the corners of a building so that stakes can be removed from the building site during site preparation.

blanked outlet: An outlet with a cover plate over the box; may be used for future lighting or power needs.

blanket insulation: Insulation consisting of wide rolls of material, often with foil covering on one or both sides and an insulating material like fiberglass in the middle.

blocking: The wooden blocks that are used to fill in the space between framing members, providing support.

bolt: A type of fastener consisting of a threaded piece of metal used with a nut and usually either a washer or metal plate.

border line: A heavy dark line around the perimeter of the drawing paper on a plan.

box nail: Nail with a thinner shank and head than common nails. Their size makes them less likely to split the wood used to build things such as crates or boxes.

brace: In fencing, the crossed or diagonal pieces of material running between the post being braced and the next post in line or a wood, metal, or concrete anchor.

branch circuit: A separate electrical path that extends from the service entrance panel and has its own overcurrent protection device.

break line: A line on a plan representing an area in a structure where a section has been removed.

bridging: Small wooden or steel pieces fitted in pairs between joists to help distribute load.

building codes: A list of rules and regulations that must be followed when planning and constructing a building. Regulations may cover aspects of construction such as the reinforcement of the concrete, service access, and utility access.

building perspective: The direction a building faces in relation to the external scenery.

burr: Sharp edge left from cutting pipe.

C

cable: Industrial wires assembled and covered with a protective element; predominant form of structural wiring used in the modern construction industry **or** a fencing material that has several strands of wire twisted together for added strength.

center line: A line showing the centers of holes and round shapes, such as drains, on a plan.

Chlorinated Polyvinyl Chloride (CPVC) pipe: Pipe that is off-white or cream in color. It is recommended for temperatures up to 180 degrees Fahrenheit and is a common choice for hot water lines.

circuit: A complete, uninterrupted path of electricity.

circuit breaker: An automatic flip switch located on an electrical circuit that breaks, or shuts off, the current when overloaded.

circuit breaker GFCI: A fixed, permanently installed type of GFCI that substitutes for a standard circuit breaker and controls the outlets within an entire circuit.

cohesion: The attraction between the molecules of a material.

common nail: A general purpose nail; the most commonly used type of nail.

compacting: In site preparation, compression of the soil with equipment designed for this purpose.

composite plywood: Plywood that has a wood veneer, or thin sheet of wood, cover laminated to some form of wood core.

computer-aided drafting (or design): A system consisting of a computer and specially designed software that does the actual drawing of plans; also referred to as CAD.

conduction heat transfer: The transmission of heat through solid matter because of contact between hot and cold areas.

conductor: The wire through which the electrical current is carried through the circuit.

construction anchor: A device used to attach walls to foundations.

controller: A device that helps protect electrical equipment by stopping current traveling through a motor during electrical surges and power overloads.

convection heat transfer: The transmission of heat as it moves through a liquid or gas.

convenience outlet: A point in the wiring system where electric power can be used.

crawl space: The space found between the ground and the first floor in structures without a basement.

crazing: The presence of numerous fine hairline cracks in the surface of a newly hardened slab of concrete due to shrinkage.

curing: The chemical reaction between water and the elements in Portland concrete that causes concrete to harden and determines its strength.

cutting bill of materials: A list of all the materials, in the actual sizes or dimensions needed, that will need to be cut to size during the construction of the project.

cutting plane: A plane showing an area where a section has been removed on a construction drawing.

D

dead load: The vertical weight of a structure; consists of the total weight of all the permanent parts of the structure, including the foundation, footings, lumber, and electrical and plumbing apparatuses.

dead man: An anchor driven into the ground or placed in concrete.

decking: Material installed on top of the support system to which asphalt or fiberglass roofing materials are attached. The decking may be either some form of sheathing material or dimensional lumber.

demand load: The amount of power that will likely be needed by an agricultural structure at any given time.

dimension line: A line spanning the space from one extension line to the next with arrows at each end; shows the size of an object on a construction drawing.

dimension lumber: Wooden building material sawn in lengths that are uniform in thickness and width.

direct current (DC): Electrical current that flows steadily in one direction through a conductor, either from the positive pole to the negative or from the negative to the positive; it is produced by a generator or battery.

double stack: Configuration of electrical wires in which supply wires coming in from the power company use a separate conduit from the wires that lead out to individual structures.

drainage: The removal or flow of water from an area.

drywall: A board-like material made of fiberboard or paper bonded to a hard plaster base. Also called sheetrock.

duplex-head nail: Nail with two heads, which allows it to be driven into the wood and still have a head extending above the surface.

dusting: The appearance of a powdery material on the surface of newly hardened concrete.

dynamic load: Load from the operation of equipment like a tractor or handling equipment in the structure.

E

electric heat tape: Tape that carries an electrical current through it to supply heat.

element: A part of a construction drawing that conveys information or enhances the information displayed on a drawing.

elevation drawing: A term used by drafters that refers to drawings of a structure as viewed from different perspectives, most commonly the top, front, and one or both sides.

environmental load: Load caused by natural factors, such as wind, snow, and earthquakes, that result in weight or pressure on a structure.

epoxy: A type of adhesive.

expansion and control joint: Either a groove made in concrete or material placed in concrete to prevent breaks or control where the concrete breaks.

extension line: A line that extends from objects without touching them to indicate their length, width, and height; used for placing dimensions on plans.

F

farmstead: A farm and its structures.

feeder wire: The wire that spans the distance from the electrical service equipment at the yard pole to the service panel at each individual structure; consist of either SE or USE wire.

fence charger: The source of electricity for electric fences. It converts power from a 120-volt electrical system or a battery into the charge sent along the fence.

fill: Added sand or aggregates used to create a level site and leave a more uniform surface under the foundation. Fill can also be used to improve drainage.

fill insulation: Insulation in a loose form (possibly small beads or a form resembling snowflakes).

finish nail: Nail with a very small head and smaller shank than common nails; used for finishing.

flat head screw: A screw with a flat head that sits flush with a surface and is easier to hide with paint.

flexible cord: Cable used to connect electrical devices to outlets; consists of three types of cords (SPT-2, S, and HPN).

fluorescent lamp: Light source consisting of a glass tube containing mercury vapor and argon gas under low pressure; electricity flowing through the mercury vapor produces ultraviolet energy that turns to visible light after striking the fluorescent coating on the inside of the tube.

footing: Large supporting blocks of concrete between the foundation and the soil. They spread the weight of the building across a larger area and make the structure more stable.

form: Structure designed to hold concrete in the proper shape and location until it sets and hardens; may be made of wood, metal, or earth.

framing anchor: A type of fastener used to attach framing members together.

framing square: A tool used in rafter layout that includes various tables and scales that are used in making cuts on the rafter.

frost line: The deepest point in the soil where frost is normally found during the winter.

fuse: A safety device that prevents the overload of an electrical circuit by "burning out" and interrupting the electrical flow.

G

gable roof: A roof style that has two sloping sides that meet at the peak of the building's roof.

gambrel roof: A roof style in which the sides slope slightly (approximately 30 degrees) from the ridge to about halfway down the roof and then slope more steeply (around 60 degrees).

gaseous discharge lamp: Type of lighting in which an electric current passes through a gas enclosed under pressure in a tube or bulb; produces light when the current moves through the gas particles.

general circuit: A circuit carrying 110-volt current and usually containing more that one electrical device.

girder: In floor framing, beams used to support loads if floors are too wide to be spanned across their full width by one piece of material.

Gothic roof: A roof style in which two curving arches meet at a point. Also referred to as an arched roof.

gravel streak: A concrete defect caused by cracks or knotholes in forms that allow the mortar to flow out and leave pockets and veins of coarse aggregate.

green lumber: Lumber with a high moisture content.

ground fault circuit interrupter (GFCI): A device that interrupts the circuit to any electrical device when a fault current exceeds a predetermined level.

ground rod: In fencing, the connection between the charger and the ground that allows a completed circuit to be made.

ground terminal: On an electric fence charger, the point of attachment for the wire that runs to the ground rod.

grounding: The electrical connection from the appliance or piece of equipment to the earth.

H

hardwood lumber: Lumber from deciduous trees (trees that shed their leaves).

header: A horizontal member found above openings for doors and windows and providing support for loads over the opening.

hidden line: A dashed line on a construction drawing that represents material in a drawing that is under other material from the view being displayed.

high pressure sodium lamp: A two-bulb lamp with an arc tube made of aluminum oxide that contains a solid mixture of sodium and mercury and produces an orange-white light.

high-tensile wire: Wire with a high tensile strength, which allows it to take a large amount of stress before breaking.

hip roof: A roof style that slopes on all four sides from a peak.

honeycomb surface: A concrete defect that results from a concrete mix that was too dry, causing air pockets to form around the unmixed dry materials.

holder: A part of a wooden form that is typically made of metal and holds wales and snap ties in place to hold the entire form together.

I

incandescent lamp: A type of lighting that produces light when electricity moves through a wire filament that then glows at a white heat.

inclusion: Hole created in a concrete wall by decaying organic matter.

individual electrical circuit: A circuit carrying 220-volts of current; usually operates a single piece of equipment.

impedance: The counter electromotive force created by the directional change in the AC circuit.

insulator: For fencing, a nonconducting wire holder that attaches to the posts and keeps the wire from making a connection with the earth.

J

jack stud: A stud that is shorter than full length used below windows and above windows and doors.

joist: The wood or metal member that rests on the sill and supports the first layer of flooring and floor and ceiling loads.

joist header: A flooring member that attaches to the sill to form a box sill; also attaches to the ends of the joists.

junction box: Electrical box in which circuit wires are routed to different locations in the structure.

K

key: A groove made in the footing that allows the concrete from the walls to bond to the concrete in the footing.

kiln-dried lumber: Lumber dried in a kiln to reduce moisture to a desired point.

L

lag bolt: A type of bolt that looks like a large screw but has a head adapted for use with an appropriately sized socket wrench.

lateral load: Pressure exerted from the side.

lath: Horizontal piece of dimensional lumber attached to the poles of a pole building. Siding is placed vertically on the structure by attaching it to the laths. Also called girts.

lightning: A visible discharge of static electricity.

live load: The weight or pressure from static and dynamic loads.

load: The weight carried by any part of a structure.

low pressure sodium lamp: A lamp consisting of two glass tubes, an inner tube containing solid sodium and a mixture of argon and neon gas and the outer tube providing a protective barrier; electricity moves through the inner tube and reacts with the gases to produce light.

M

mansard roof: A roof style that slopes on all four sides from the flat upper part of the roof.

marker nail: A nail driven through a wooden form from the outside to mark the desired height of the concrete if it is not being poured to the top of the form.

masonry construction: Type of construction in which concrete or masonry blocks are the primary building material. Buildings are constructed by pouring concrete in forms or laying blocks.

mastic: Adhesives that use cohesion to attach large surface areas of material.

measuring line: A line used in measuring rafters that runs parallel to the side of the rafter and extends from the middle of the ridge board to the outer edge of the top plate.

mercury vapor lamp: A two-bulb lamp with an inner arc tube made of quartz that contains high pressure mercury vapor; produces greenish-blue light.

metal halide lamp: A two-bulb lamp that contains compounds of metal and halogen; produces naturally colored light.

N

National Electrical Code (NEC): A code sponsored by the National Fire Protection Association that provides minimum standards for electric wiring practices and materials.

neon tester: A simple device that can be used to test a 120-volt or 240-volt electrical system; a glowing light indicates that voltage is present in a circuit.

neutral wire: A wire that conducts electricity from the appliance back to the source, completing the electrical circuit.

nominal dimensions: The dimensional measurements of lumber before any processing.

nonmetallic sheathed cable: Most common type of cable used in building construction; consists of three forms (NM, NMC, and UF).

nonveneered panel: Sheathing material, such as oriented strand board (OSB), particle board, and wafer board, made from wood flakes, chips, or fibers that are combined with suitable resins and glues and shaped into panels.

O

object line: The very distinct line used to draw the object on a construction drawing.

Ohm's Law: A mathematical formula that expresses the relationship between electromotive force (E), electric current (I), and resistance (R); $E = I \times R$.

ohmmeter: A device that measures resistance.

organic material: Matter produced by plants and animals that is found in or on the soil.

outlet-type GFCI: A GFCI that is permanently mounted in an outlet box; protects all devices plugged into it.

overcurrent device: A device, such as a fuse or circuit breaker, that limits the amperage in any wire to the maximum permitted.

P

pan head screw: A type of screw with which a small head remains above the surface after insertion.

parallel wiring: A wiring method with multiple outlets that allows power to flow separately to each individual fixture in the same circuit.

Phillips screw: A screw with a cross slot on its head.

pitch: In construction, the steepness of a roof. Pitch may be expressed as slope in a ratio of the number of inches of rise per foot of run. Pitch may also be defined as a fraction that is a ratio of the rise to the span of the structure.

plan: A drawing of a proposed structure containing a pictorial representation of the structure and information about it, such as the various dimensions of the structure and the placement of any doors or windows.

plug-in GFCI: A type of GFCI designed for use in existing electrical systems that do not have GFCIs installed; it plugs into a regular receptacle and protects only those appliances plugged into it.

plywood: Sheathing material made of thin sheets of wood laminated to a desired thickness.

polarity: Direction of electrical flow.

pole buildings: Buildings in which large timbers are placed in the ground and serve as the weight-bearing skeleton of the building.

Polybutylene (PB) pipe: A flexible plastic pipe, usually gray in color, that is available for use with cold or hot water.

Polyethylene (PE) pipe: A flexible black plastic tubing primarily used for installing underground water service lines.

Polyvinyl Chloride (PVC) pipe: Rigid white plastic pipe generally used for cold water supply and waste disposal lines.

portable GFCI: A GFCI that has an extension cord and is portable; plugs into standard outlets.

portland cement: A common cement made mainly of limestone, clay or shale, and gypsum combined using a special process of grinding and heating.

portland cement: A common cement made mainly of limestone, clay or shale, and gypsum combined using a special process of grinding and heating.

positive terminal: On an electric fence charger, the point of attachment for the wire that carries the current to the fence.

positive wire: A wire that acts as a conductor of electrical power.

post driver: A weighted metal tube with a sealed top and handles on the sides. The open end of the post driver slides over the top of the post and is raised up and slammed down on the post to drive it to the correct depth.

post hole digger: 1. A hand-operated tool consisting of two blades, each with a separate handle, that are joined by a hinge. Soil is removed by digging the blades into the earth and then pulling the handles outward and lifting the digger upward. 2. A power-driven tool with an auger that bores a hole into the ground.

post maul: A large sledgehammer-type tool for driving sharpened wooden posts.

power equation: The mathematical formula that expresses the amount of power used in an electrical circuit or system, indicating the relationship between wattage (P), amperage (I), and voltage (E); $P = I \times E$.

purlin: Pieces of dimensional lumber that are nailed perpendicular to rafters to provide a surface to which metal roofing is attached.

purchasing bill of materials: A list including the materials identified on the cutting bill of materials in their standard sizes and all other materials needed to construct the project.

Q

Quonset roof: A type of arching roof that forms a semicircle.

R

R-value: The mathematical expression of a particular insulation's ability to resist the transfer of heat through the material.

radiant heat transfer: The transmission of radiant heat, which is given off by sources of heat, such as the sun.

rafter: A structural member that spans from a wall's top plate to the ridge board of the roof to support the roof.

rebar: Steel rods used for reinforcing concrete.

reinforcement: Rods or wire mesh made of steel used to strengthen concrete and help it resist forces acting on it.

ridge cut: A cut made at the end of the rafter that fits against the ridge board and allows the rafter to fit flush against the ridge. Also called a plumb cut.

rigid insulation: Insulation in the form of sheathing, often covered with foil on one or both sides.

ring-shank nail: A type of nail with a cupped head to increase its holding ability.

rise: The vertical distance from the top plate to the ridge.

rock pocket: A concrete defect caused by cracks or knotholes in the form that allow the mortar to flow out, leaving pockets and veins of coarse aggregate.

roofing nail: A type of nail with a very wide head; used for nailing shingles in place.

rough sill: A horizontal framing member attached to the top of jack studs to form a rough base for a window.

run: The horizontal distance covered by one rafter from the outside edge of the top plate to the exact center of the ridge.

rust stain: A concrete defect caused by steel reinforcement that has worked to the edge or surface of the concrete.

S

sand streaking: A concrete defect that results in small ribbons of sand running across the surface of the concrete; caused by a mixture that was too wet.

scale: In construction, an adjustment in the size of a drawing that reflects the size of the object being drawn.

scaling: A concrete defect that occurs when the surface of hardened concrete slabs break away to a depth of 1/16 to 3/16 of an inch; caused by the freezing and thawing of newly placed concrete.

screw-shank nail: A type of nail with a twisted shaft used where good holding ability is needed.

seat cut: A notch cut out of a rafter that allows the rafter to be seated on the top plate. Also referred to as a bird's mouth.

series wiring: Wiring system in which all outlets are connected.

service wire: Wire that carries power into the home or building to the service entrance panel; may be either SE or USE wire.

sheathing: The part of a wooden form that forms the sides of the form.

sheathing material: Panels generally made of wood or wood product manufactured in one of several ways.

shed roof: A roof style with only a single pitch, with no ridge.

shock: The passing of an electric current through the body and the body's reaction to it.

short circuit: A problem that occurs when wires in the same circuit come into contact, causing the flow of electrical current to move from its desired path.

siding: Material placed on the outside of a building to seal and enclose the building from the weather.

sill: Material attached to the foundations that supports the floor joists and attaches the building frame to the foundation.

single stack: A configuration of wires in which wires that travel into the meter from the power company and wires traveling out to individual structures are both contained within a single conduit.

slump test: A test done to determine if concrete is of the proper consistency and whether more or less moisture is needed; the test is performed by measuring the amount of slump, or drop in height, of concrete that has been poured and tamped in place in a cone, which is then removed.

snap tie: A part of a wooden form consisting of a piece of wire that runs through the concrete wall and helps hold the forms the correct width apart.

softwood lumber: Lumber from evergreen trees.

sole plate: The structural member forming the bottom of the wall to which the studs are nailed.

span: The total distance from the outside edge of one wall to the outside edge of the other wall, equal to twice the run.

spreader: A part of a wooden form that is placed inside the form to keep its sides apart while the concrete is poured.

square: When roofing, a measure of roofing material equal to 10' × 10', or 100 square feet of finished roofing.

stack: The grouping of wires at the yard pole.

staple: A U-shaped fastening device. It may be used to attach wire, plastics, or vinyl.

static load: Load from anything occupying the structure, such as livestock, equipment, or stored products.

stud: A vertical wall member that provides the main support for the wall in frame construction.

subflooring: The first layer of material applied over the floor joists.

subgrade: A surface leveled off in preparation for laying a foundation.

superplasticizer: Concrete additive that increases the strength of the concrete by altering it so that it needs less water to be workable.

surge arrestor: A device that removes high voltage charges from the system by breaking the circuit and then diverting the electricity to the ground in order to drain power surges.

surge suppressor: A device used to protect electrical equipment by providing a receptacle or bank of receptacles with a breaker that automatically trips when the electricity spikes.

switch loop: A pair of wires brings the power to the switch from the source through the lighting box and carries it back to the light.

symbol: A pictorial representation of information that is included on the construction drawing.

T

tail: The part of a rafter that forms the roof from the side of the building to the end of the roof. Also called the overhang.

tail cut: A cut made at the end of the rafter that is parallel with the wall.

tensile strength: The ability to withstand tension or pull.

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three-phase power: A form of alternating current; utilizes three hot wires, carrying electrical current at different stages of alternation.

tie: A part of a wooden form that keep the two sides of the form apart to give the wall the desired thickness.

top plate: The horizontal member at the top of a wall on which the trusses or rafters rest.

topography: The relative positions and elevations of the natural or man-made features of an area that determine the surface configuration of the land.

treated lumber: Lumber that has been chemically treated for preservation.

trimmer stud: Vertical wall framing member that forms the sides of door and window openings as well as rough openings; supports the header.

truss: A structural assembly of lightweight material consisting of connected triangles (rafters, joists, or beams) used to create a system designed to support heavy loads over a considerable span.

Type R wire: A type of interior wire; divided into three categories (RH, RHH, and RHW).

Type T wire: The most commonly used type of interior wire; divided into four categories (TW, THW, THHN, and THHW) based on the wire's ability to withstand environmental and temperature conditions.

U

UL listing: Mark indicating that representative samples of the product have been tested and evaluated by the Underwriters Laboratories, Inc. with reference to nationally recognized safety standards for electric shock, fire, and related safety hazards.

underlayment: A second layer of material attached to the subflooring; it lies between the subflooring and the finish floor.

V

vapor barrier: A specially constructed protective material attached to the inside of the underground portion of a concrete wall to eliminate condensation.

ventilation: The movement of air, either naturally (because of convection air currents) or mechanically, through an area.

vertical load: Pressure exerted from above.

volt-ohm-milliammeter (VOM) meter: A tester that displays the voltage and polarity of the circuit as well as an accurate measurement of circuit resistance and amperage by combining a voltmeter, ohmmeter, and ammeter in the same casing.

voltage (v): The pressure created by electricity moving through the wire or conductor; measured in volts.

voltage drop: The loss of electrical pressure from the source to the point of use.

voltmeter: A device that measures voltage across two points in an electrical circuit.

W

wale: A part of a wooden form consisting of a 2" × 4" board that prevents the wall from bulging outward due to the weight of the concrete.

water stop: Synthetic material placed between concrete construction joints to stop water from entering through the joints.

wattage (w): A measurement of the total electrical power within a system; calculated by multiplying amps and volts.

watt-hour meter: A meter that measures and instantly records electrical consumption in watts or kilowatts.

wire stretchers: A tool that pulls wire taut before it is fastened to the fence posts.

wire tie: A part of a wooden form consisting of a piece of twisted wire used on the end of the form to hold the sides the correct width apart.

wood frame construction: Construction involving the use of weight-bearing upright wooden members for the walls of a building.

woven wire: A fencing material in which wires are woven together horizontally and vertically to form a mesh.

Y

yard pole: A centrally located pole where the service drop from the power company ends; the power is carried to the individual buildings of a farmstead by feeder wires.

Z

zoning laws: A set of local restrictions and requirements that determine what type of building may be done in a particular area. Regulations may include the type of building permitted, the size of a structure, the permits required, the style of construction, etc.